551

THE
SHAPE
OF
THE
EARTH

PATRICK
LYNCH

PATRICK LYNCH is now well known for his three book series on world history—details of which are printed on the back flap of this wrapper—and for his collaboration with Barbara Sewell on *The Story of Ancient Egypt*.

In this new book he has taken for his subject the physical environment of man and describes, in a simple way, the position of the earth in the universe, the structure of the earth and the movements of rock, air and water.

Once again the author has collaborated with David Chalmers who has provided many striking illustrations; and there are also many photographs.

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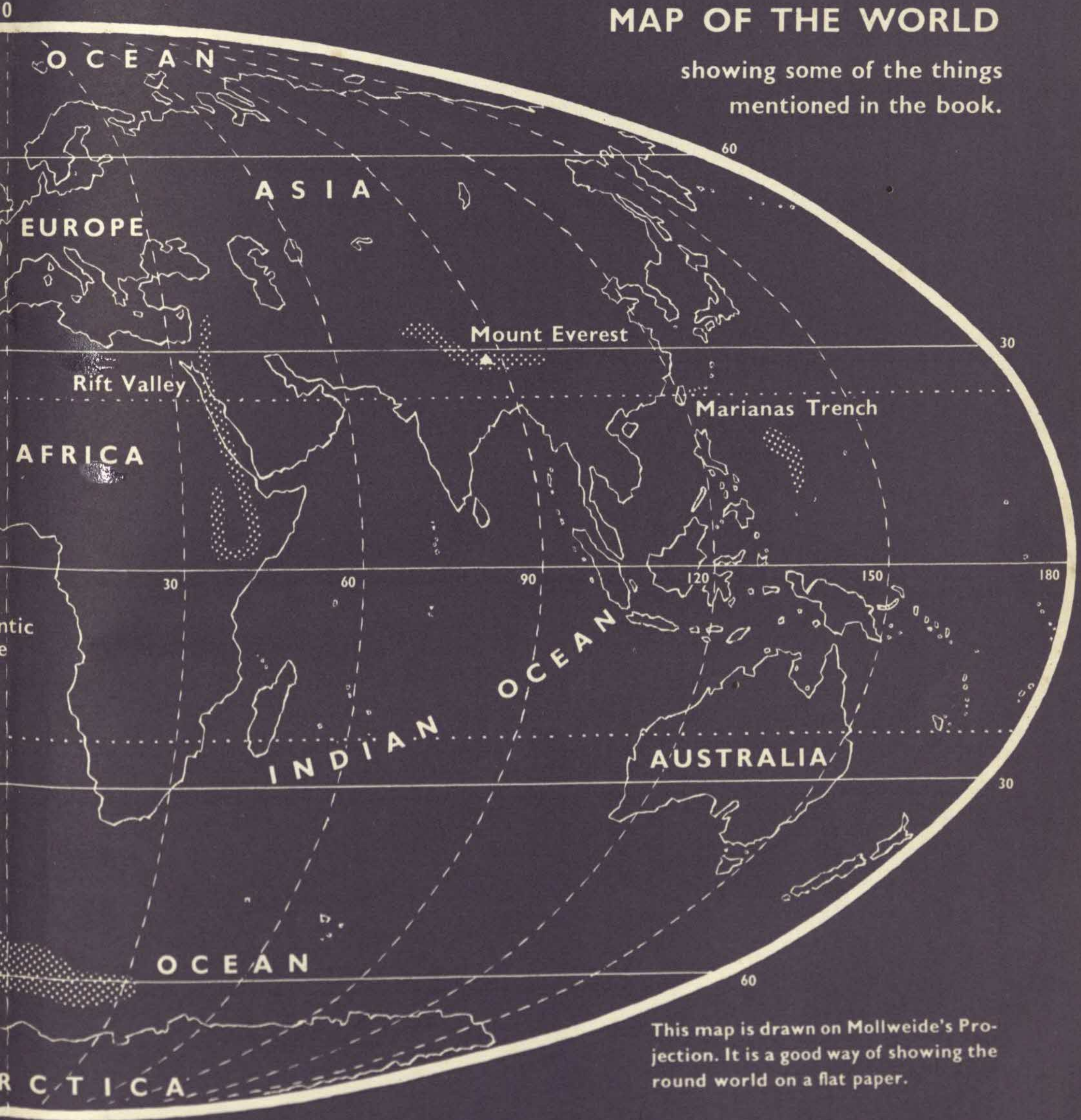
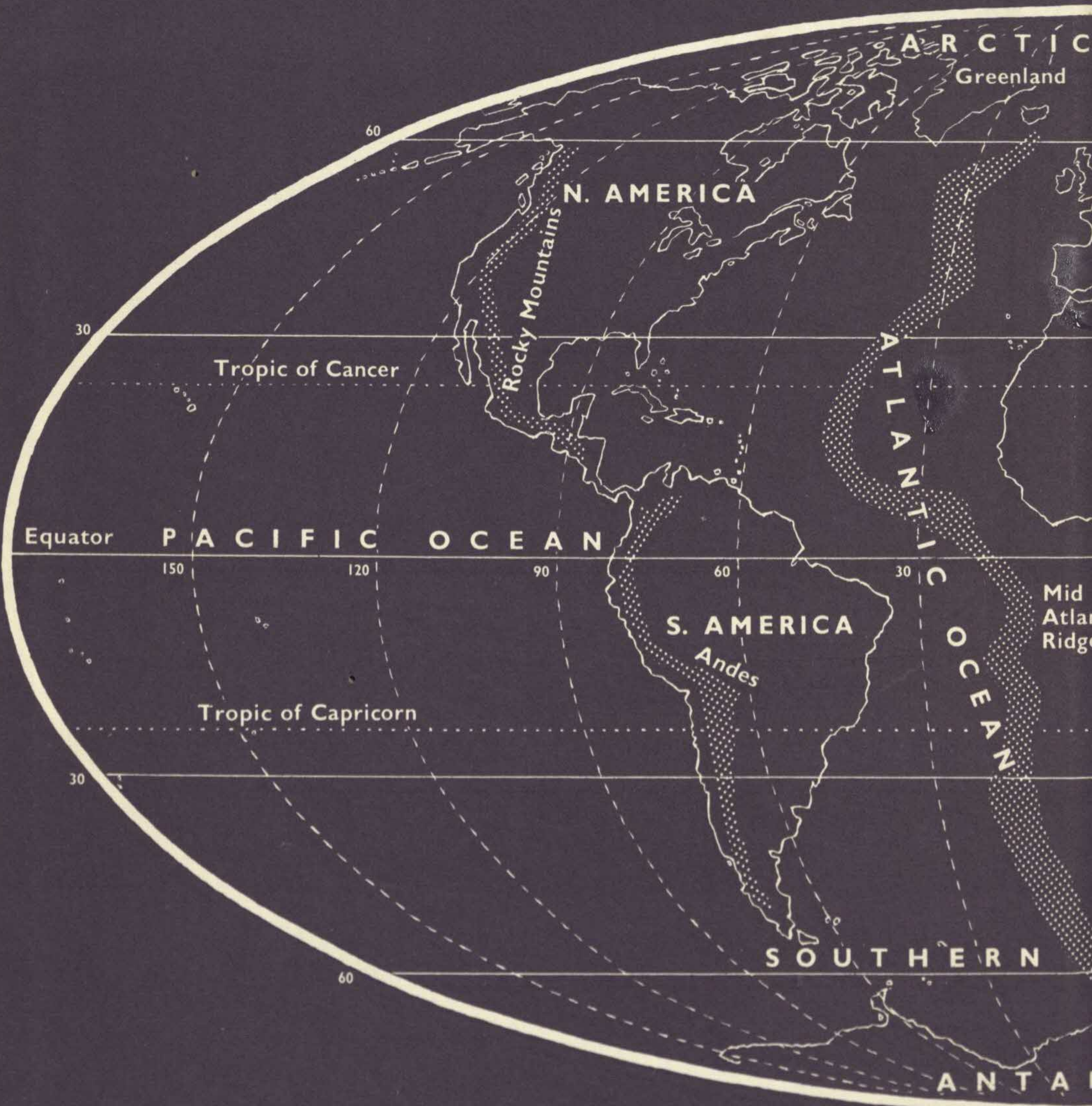
MAP OF THE WORLD

showing some of the things
mentioned in the book.



This map is drawn on Mollweide's Projection. It is a good way of showing the round world on a flat paper.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THE SHAPE OF THE EARTH

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By

PATRICK LYNCH

Illustrated by

DAVID CHALMERS

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PREFACE

THERE is very little of Earth's surface which has not been explored and described, but we still have much to learn about the position of Earth in the Universe, her structure and the movements of rock, air and water. Although fresh discoveries are being made daily, this book aims at summarising in a simple way the present state of Man's knowledge of physical geography. It is hoped that it will appeal chiefly to young people aged between 10 and 15.

A glossary at the end explains words which are spelt in capital letters in the text, and also serves as an index.

I would like to thank David Chalmers for the care he has taken with the illustrations.

P.B.L.

An astronomer looks through the wide-angle telescope which is used for mapping the universe. (Photo: U.S. Inf. Service.)

STARS AND SPACE

THE Sun rises, moves across the sky and sinks in the west. The Moon seems to race through wind-driven clouds. From month to month the stars appear to change their positions so that sometimes we see a group of stars making the pattern of a plough in the correct position for work and at other times we see *the plough* apparently standing up on its handles! Only Earth seems firm and still. But, just as when we see the telegraph poles rushing past the window of a train, we know that what seems to be is not always so. It is the train which rushes past the telegraph poles and the Earth which spins and revolves around the Sun. So, on our journey through space we see Sun, Moon and stars from different angles and imagine that they are all moving around us. The Moon truly moves around the Earth but it is the clouds which race across its face on windy nights and make it look as if it is travelling at speed.

Earth is just one of nine PLANETS which travel at varying speeds around the Sun. But not even the Sun is still; it too is travelling and we are travelling with it.

We are spinning through space on a great Catherine-wheel of stars. That cloudy shining streamer which we see above us on a clear night is the Milky Way and our Sun is but one of the stars which make it up. In this GALAXY the stars cannot be counted but their number is estimated in thousands of millions. At a speed of 200 miles per second the Sun is taking Earth and its other PLANETS on a journey which lasts for 200 million years, for this is the time it takes the GALAXY to revolve.

So great are the distances which ASTRONOMERS have to measure that the miles which we use on Earth are far too small. The greatest speed Man can understand is the speed of light which travels at 186,000 miles per *second*. Radio waves which travel at the same speed as light can be sent the 25,000 mile journey around the world in just under 1/7 of a second, so that if a broadcaster could hear his voice after it had made that journey he would feel as if he were speaking in a room with an echo.

The light from the Moon takes $1\frac{1}{4}$ seconds to travel the 239,000 miles to Earth; and the light from the Sun, 93 million miles away, reaches us in 8 minutes 20 seconds. Light from the Sun's remotest planets Neptune and Pluto takes over 5 hours to reach us.

If we could see it from a greater distance the Milky Way galaxy would look like the edge of a wheel. Our Solar System is only a speck on its edge.

Yet these distances are as nothing compared with the measurements of the UNIVERSE. Our own Sun is just another star—one of millions in the Milky Way—but its nearest neighbour is over four *light years* away from us. In other words the light from this star which is known to astronomers as PROXIMA CENTAURI has been travelling at 186,000 miles per second for over four years before we see it. This is a distance which can be put into earthly miles if we use some very clumsy figures, for it is 25,000,000,000,000 or 25 BILLION miles from us. If a scale model of the universe was made with the Sun the size of a match head the tiny Proxima Centauri would have to be placed 100 miles away. Such numbers as million and BILLION are difficult to understand and nearly as difficult to write; therefore to give the idea of these vast numbers we use a method which mathematicians find convenient. In algebra we learn that x *squared,* which we write as x^2, means x multiplied by itself, and that 2^2 must equal 4. If we add a nought to 10 we *square* it and the answer is 100. So $10^2 = 10 \times 10 = 100$, and 10^3 (or 10 *cubed*) $= 10 \times 10 \times 10 = 1{,}000$. By this means we can write very large numbers in a small space, for $10^6 = 1{,}000{,}000$—a figure one followed by six noughts which we call a *million.*

In these terms we can say that the Sun is 93×10^6 miles away and that Proxima Centauri is 25×10^{12} miles away. Now with the measurement known as a *light year* and this convenient method of writing large numbers we can look at some other astronomical figures. Our own GALAXY of the Milky Way contains one hundred thousand million (10^{11}) stars of which our Sun is quite an ordinary example. In shape the galaxy is a disk somewhat bulging at the centre which has out-reaching spiral arms of stars, gas clouds and dust. On one of these arms is our Sun, and as we look at the band of the Milky Way in the sky we are looking at our galaxy edgeways, across thousands of *light years.* For the disk of our galaxy is about 100,000 *light years* or about 6×10^{17} miles wide, and about 5,000 *light years* in thickness. We can, however, see stars all around us in the sky. These which we can see without the aid of a telescope are only the close neighbours of a thousand *light years* and so are all contained well within the thickness of the galaxy.

If we stand in the middle of a street we can see houses all around us, yet that street may be on the edge of a town the shape of which we cannot see. So it is with us in our galaxy. We cannot see its shape for there are stars all around us, but the appearance of the Milky Way tells us a little and the rest we know from the appearance of other much more distant clouds of stars.

Although the human eye cannot see any single star which is more than one thousand *light years* away it can see groups of stars which are much more remote. In the northern sky may be seen a CONSTELLATION known to astronomers as Andromeda. There is nothing very remarkable about the stars in this constellation for they are quite ordinary suns in our galaxy, but they act as markers for a faint and distant patch of light known as the NEBULA in Andromeda. The great NEBULA is not really a cloud at all but another GALAXY, the twin of the Milky Way and 1,500,000 *light years* away from us.

The Andromeda Nebula and the Milky Way are part of a comparatively small group of galaxies, but beyond them are more and more galaxies—100,000,000 (10^8) of them within reach of the modern telescope peering out through 1,000 million *light years* of space. Imagine that on some PLANET of one of Andromeda's million suns there are some very clever astronomers who have built some sort of super telescope with which they can study not only the Milky Way but also the details of the suns and planets which it contains. They focus it upon Earth and peer through it wondering if they will see signs of human life. To their disappointment they find that on Earth the only two-legged animals are monkeys and apes. Because Earth is 1,500,000 *light years* from them they would be seeing the world of 1½ million years ago—before Man had arrived on the scene!

But we will not worry about astronomers who live so far away that they cannot even see us. The astronomers of our own planet have given us enough to think about for we might well ask "How do they know?" The astronomer observes, measures and calculates. His chief tool is the telescope, and, although a three-inch model built by an amateur in his back garden would show many things which cannot be seen by the naked eye, to discover the secrets of the distant galaxies the astronomer has to use the great 200-inch telescope at Mount Palomar, U.S.A. With specially sensitive photographic plates which are exposed for many hours he can collect and examine the light from otherwise invisible NEBULAE.

From the window of a moving train a distant church will remain in view for a long while and appear fixed, whereas a tree much closer to us will come into sight from one side of the church, cross in front and disappear on the other. A mathematician could tell us how far the tree is from the railway line if he measured how many degrees to left and right of the church it seemed to be from two points a mile apart on the line.

The astronomer uses the same method to tell us how far away are some of the closer stars. The more distant stars are described as 'fixed' for they never appear to change their positions. Stars which are closer to us would appear to be in slightly different positions when viewed from points 100 million miles apart. The only problem is how to make such a journey through space; but it is one which we all make every year. In one year Earth travels round the Sun and in six months we fly from one side of the Sun to the other. The Sun is 93,000,000 miles away; therefore between January 1st and July 1st we change our position by 186 (93 × 2) million miles. The astronomer makes two careful measurements of the position of a star at an interval of six months and knows that he has travelled, not one mile like the mathematician in the train, but 186,000,000 miles. Although the differences in the position of any star may be very slight the figures which the astronomer obtains are enough to tell him that PROXIMA CENTAURI is 25×10^{12} miles away.

The distances of other more remote stars are calculated by comparing their brightness with similar stars of known distance. If a star is only one quarter as bright as another of the same type it will be twice as far away.

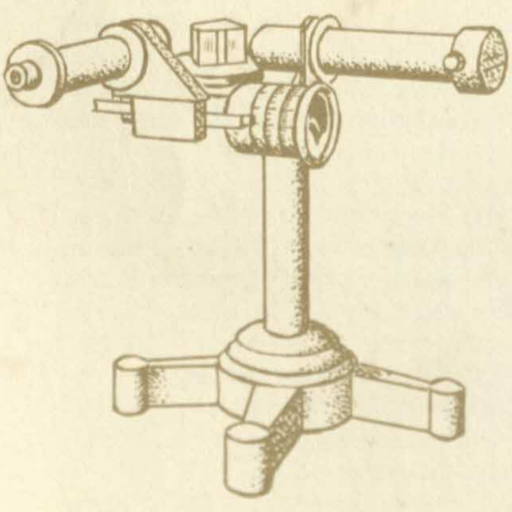
THE RAINBOW LIGHT

THE seven colours of the rainbow are caused by little drops of moisture in the air catching the Sun's light and spreading it into its SPECTRUM. With an instrument known as a SPECTROSCOPE, which works far more accurately than a rain drop, the SPECTRA of the light from the Sun and other stars can be studied and compared. Astronomers have discovered that certain dark lines which cross the coloured band are caused by the chemical substances which are burning in the star whose SPECTRUM is being examined.

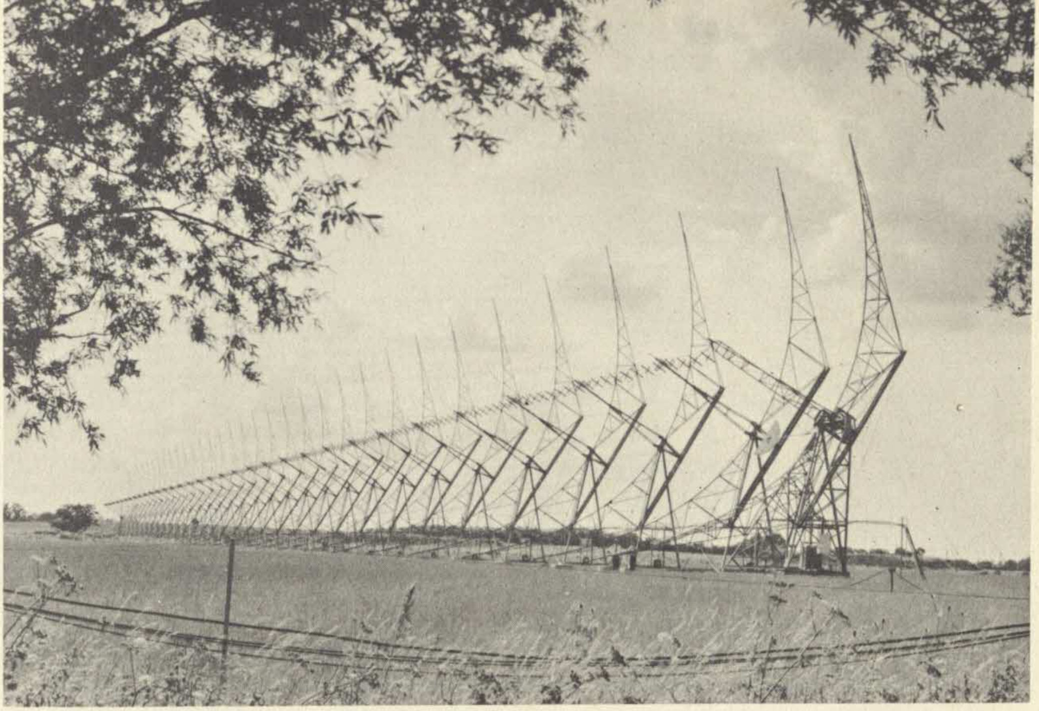
Not only can the astronomer discover what a star is made of by studying its spectrum; he can also tell whether it is moving. A light which is moving towards us has its rays bent more towards the violet end of its spectrum, whereas, if a light is moving away from us, the red end of the coloured band appears to be more important. But do not imagine that a white light on the back of your bicycle will appear red if you ride very quickly away from a policeman! These differences only appear if the light is viewed through a spectroscope (which is not part of a policeman's equipment!) and if the light is moving at several thousand miles per second.

Astronomers who are accustomed to think in terms of thousands of miles per second or BILLIONS of miles, and realize that small differences between the rainbow light of one star and another may show enormous differences in size, make-up or position; are able to tell us that all GALAXIES are moving away from each other and that the most distant ones are moving the fastest—like spots on the surface of a balloon which is being rapidly blown up. The NEBULA *Hydra* for instance is 12×10^8 (1,200 million) light years (*light years* not miles) away and is moving away from us at 38,000 miles per second.

With the help of the great telescope at Mount Palomar a photograph was taken in 1960 of a galaxy which is thought to be 6,000 million (6×10^9) *light years* away. If the speed of galaxies continues to increase the farther away they are from each other this latest and most distant discovery may well be travelling close to the speed of light. Somewhere beyond 6×10^9 *light years* there may well be galaxies rushing away from us at 186,000 miles per second—the speed of light itself. Their light can, therefore, never reach us and they will forever remain invisible even to the most powerful telescopes. (There you have the perfect recipe for becoming the Invisible Man—travel at 186,000 miles per second and no one



The Spectroscope can break a beam of light into its wave lengths by means of a prism.



The Radio Telescope of the Mullard Laboratory, Cambridge, has aerials moving on tracks as well as this fixed aerial 1,450 feet long. With the Radio Telescope some of the most distant galaxies can be studied. (Photo: Mullard Ltd.)

will see you—but neither would you see anyone else!)

Not even the astronomer's latest tool, the radio telescope, can penetrate farther for the radio waves which it receives from outer space also travel at 186,000 miles per second.

But by using a radio telescope to study and compare distant galaxies a professor of Radio Astronomy has been able to form the opinion that the universe was created in a huge explosion ten thousand million years ago, that the pieces are still flying apart and that they will continue to do so for another few thousand million years. Then as the effect of the explosion dies away the universe will end. There is no need for us to worry, however, for even this little planet Earth will last for many millions of years yet.

The first piece of astronomical equipment which we mentioned was a telescope, but the final work is done with a pencil and paper or with an electronic computor, for it is with these that astronomers work out what must be happening in places where they cannot see.

Many of us ask sooner or later, "Where does the universe end? What lies beyond it? How did it start?" The only answers which can ever be given to these questions are that: For us the universe must end somewhere beyond 6,000 million *light years* for we can never see much farther. But only God knows what lies beyond or whether it goes on for ever. Astronomers may argue whether the universe was created in some sort of super explosion thousands of millions of years ago or whether it has existed for ever and will continue to do so. These answers will never be known and the sight of the night sky with its uncounted galaxies of millions of stars will continue to remind us that the Earth is an insignificant speck in the vastness of space and that Man's brain is a poor thing, for the more he discovers the more he stands amazed.

THE SUN'S FAMILY

THE boy wanted to make sure that his book would not be lost so he wrote in it as follows:

Tom Brown,
17 Station Road,
Sometown,
Someshire,
England,
Europe,
Earth.

He could probably have continued so that even an imaginary space postman might have found him, for the rest of the address would be:

Planet No. 3,
The Solar System,
The Milky Way Galaxy,
The Universe.

As we saw in the last chapter our Sun is just one of countless millions (perhaps about 10^{20}) stars in the universe. Many of these stars may well have planets revolving around them upon which there could be living creatures, but we cannot expect our space-postman to find out for us; for even if he visited only a few he would have to travel for many years at the speed of light.

The only living things which we know are those which we find upon our planet Earth. In all of them, as in our own bodies, the substances carbon, nitrogen and water are found. We do not find plants and animals made of iron, stone or glass but it is possible to imagine, that on another planet where conditions are completely different from those on Earth, there may be forms of life based upon such substances as sulphur or silicon, and which would not need the oxygen, nitrogen and water upon which we depend. Even if there were such strange creatures, somewhere in the universe, they would not be able to exist under the conditions which we like; nor could life as we know it exist in the gases, poisonous to us, which would form the ATMOSPHERE of their planet. So when we ask whether there are living things on other planets than our own we are really thinking about life of the type we know on a planet rather like our familiar and friendly Earth.

Before there can be any living things there must be:

(i) a planet to live on,
(ii) the planet must be neither freezing cold all over nor boiling hot,
(iii) there must be an ATMOSPHERE on that planet,
(iv) that atmosphere should contain the gas oxygen and some nitrogen and must not be poisonous,
(v) there must be some water on the planet.

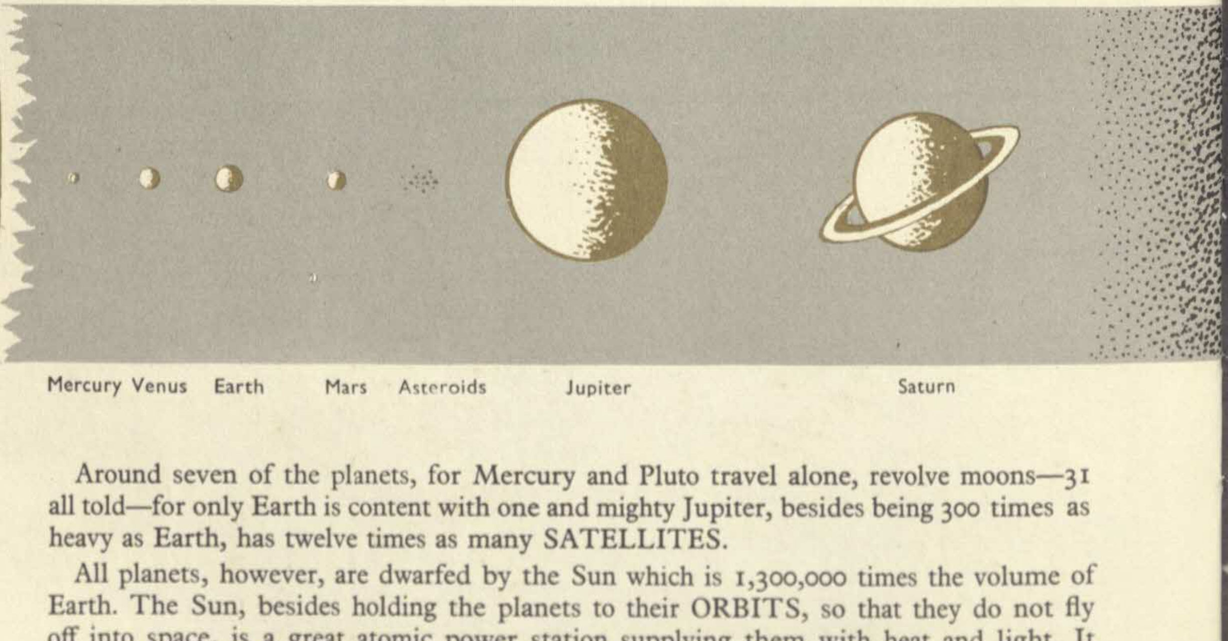
Of all the many billions of suns which are the stars of the universe perhaps only one in a thousand has a family of planets. Only one planet in a thousand may have the correct temperature and of these it may be that only one in a thousand has an atmosphere. Only one in every thousand atmospheres may contain oxygen ... and so on ...! Even when all the chances have been taken into consideration there are so many suns to chose

An imaginative view of Mars, seen from its outer moon, Deimos.

from that it is still likely that somewhere there are several million planets on which there are other living things, but what these 'creatures from outer space' are like we shall never know!

The stories of space exploration which some of us like so much tell of fantastic people from Mars or Venus or even from Jupiter and Saturn. These planets are members of our own SOLAR SYSTEM for one cannot seriously imagine travelling to the planets of another sun several *light years* away. But whether there is any life at all on our neighbouring planets is something of which the story writers cannot yet be sure.

We know that Earth travels round the Sun and takes a year to make the journey. But the Sun is also at the centre of the paths taken by the other eight planets which belong to the Sun's family. As our address in space shows, Earth is the third planet in the SOLAR SYSTEM. Closest to the Sun is Mercury which revolves at a distance of 36 million miles, and the most distant is Pluto, 3,500 million miles away. If, in imagination, we followed the rays of the Sun we would first of all cross the ORBIT of Mercury and then the ORBITS of Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. Between Mars and Jupiter lies a band of small bodies known as the ASTEROIDS—about 80,000 tiny planets, the largest of which could just cover England if it collided with Earth, and most of the others just lumps of matter a few miles across.



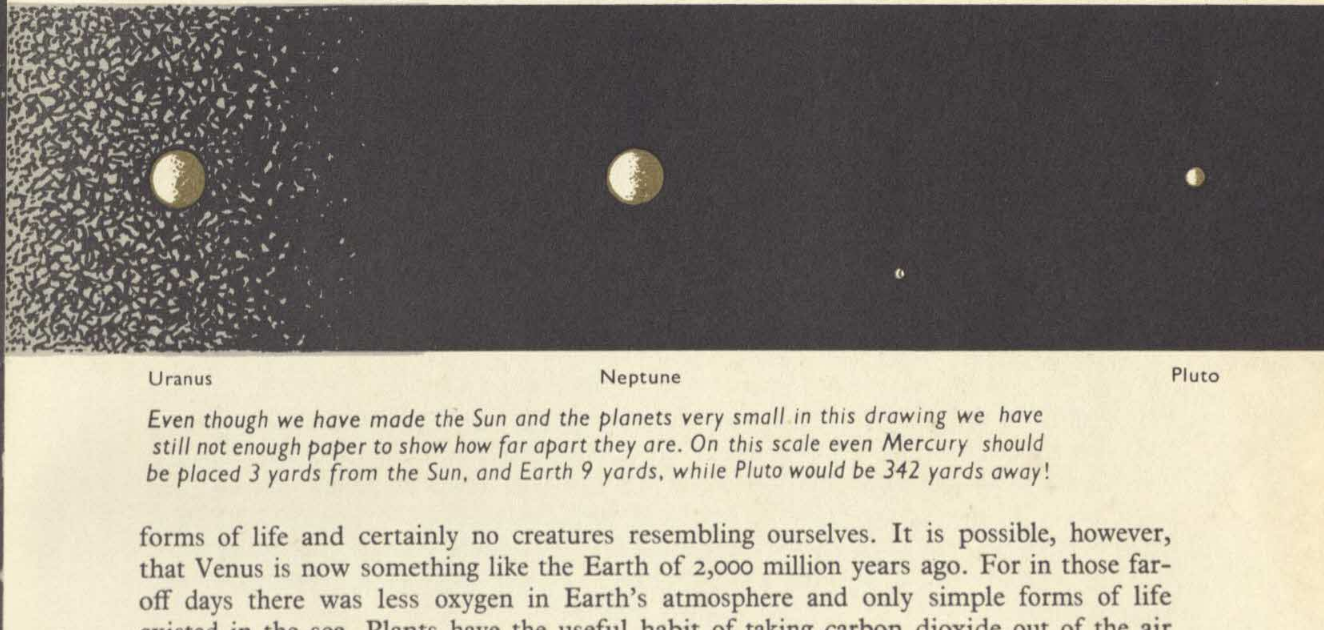
Around seven of the planets, for Mercury and Pluto travel alone, revolve moons—31 all told—for only Earth is content with one and mighty Jupiter, besides being 300 times as heavy as Earth, has twelve times as many SATELLITES.

All planets, however, are dwarfed by the Sun which is 1,300,000 times the volume of Earth. The Sun, besides holding the planets to their ORBITS, so that they do not fly off into space, is a great atomic power station supplying them with heat and light. It follows then that the nearest planet, Mercury, must be very much hotter than Pluto shivering on the edge of the solar system. Mercury, which always keeps the same face turned towards the Sun, has on one side a temperature which would melt lead and on the other side is quite dark and colder than we can ever imagine. The five outermost planets from Jupiter to Pluto are intensely cold—perhaps 200 or 300 degrees below the freezing point of water and very much colder than the lowest temperature ever recorded upon Earth. Even if living things could stand such intense heat or cold there could be no life on any of these planets for Mercury is without air, and the atmospheres of Jupiter, Saturn, Uranus and Neptune contain the poisonous gases methane and ammonia.

The space explorer of the future will turn his attention first to the two planets which are most like the Earth and which travel around the Sun at distances which would neither freeze nor fry their inhabitants. It is only on the two planets Venus and Mars that there is any possibility of life, but although astronomers have peered and calculated and argued they still cannot be sure.

Venus is almost the twin of the Earth in size. It is 67 million miles, whereas Earth is 93 million miles, from the Sun. Instead of making its ORBIT in $365\frac{1}{4}$ days, as Earth does, it takes $224\frac{3}{4}$ days; so that on Venus a year would last 225 days with a shorter 'leap' year of 224 days once in every four!

Although no planet ever comes nearer to us than Venus which at times is only 25 million miles away, astronomers have not been able to see any detail of the Venusian landscape for the planet is blanketed with an atmosphere which prevents any watcher on Earth from peering below the clouds. By using the SPECTROSCOPE astronomers have found that there is no oxygen but plenty of carbon dioxide in the planet's atmosphere. Carbon dioxide gas surrounding a planet has the same effect as a giant greenhouse which keeps in the Sun's heat. Therefore Venus is probably very hot, but little else can be told. Some believe that it is one vast and completely dry desert of wind-blown dust, others that it is a planet covered by oceans. Since there is no oxygen gas there can be no advanced forms of life and certainly no creatures resembling ourselves. It is possible, however, that Venus is now something like the Earth of 2,000 million years ago. For in those far-off days there was less oxygen in Earth's atmosphere and only simple forms of life existed in the sea. Plants have the useful habit of taking carbon dioxide out of the air and releasing oxygen, and much of the oxygen in our atmosphere to-day we owe to plants, which for millions of years have been helping to make Earth a place fit for animals to live in.



Even though we have made the Sun and the planets very small in this drawing we have still not enough paper to show how far apart they are. On this scale even Mercury should be placed 3 yards from the Sun, and Earth 9 yards, while Pluto would be 342 yards away!

The picture of Venus as a hot and almost lifeless planet is not as exciting as the one imagined by a German astronomer of a hundred years ago. He tried to explain a strange glow which seemed to come from the planet by the theory that the Venusians were setting forests on fire to celebrate the coronation of a new king!

No king, no subjects, no forests even but only the possibility of the very simplest forms of life;—such is Venus, so we are left with Mars, the Earth's next nearest neighbour in the solar system.

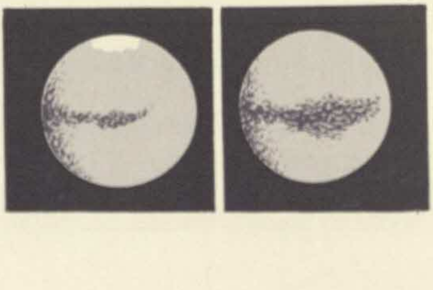
Mars is farther from the Sun than Earth is, being at a distance of 142 million miles. The Martian year is 687 days long for that planet takes nearly twice as long as Earth does to complete its orbit, so that Earth and Mars come closest to each other once in every two years. As the orbits of none of the planets are perfectly circular but rather ELLIPTICAL the distances between one planet and another do not always remain the same. At intervals of about 15 years the two planets come as near to each other as 35 million miles. It is at these times that astronomers can study Mars most thoroughly, and although Venus can come 10 million miles closer to Earth, it is Mars which shows itself more clearly. But even with the greatest telescopes astronomers cannot see as many details of the Martian landscape as they would like. It is no wonder then that there should be a great deal of argument about certain fine lines which are seen on the face of Mars. For a long time it was thought that the lines were canals which intelligent people had dug to take water to their thirsty crops. Some astronomers have vivid imaginations but what do they really know about life on Mars ?

Mars has a North and a South Pole just as Earth has, and during the Martian winters these poles appear to be covered with caps of snow or hoar frost which disappears with the coming of spring. Fringing the white polar areas are darker patches which seem to spread as it grows warmer. Most astronomers believe that the dark patches are caused by simple forms of plant life like the mosses and lichens which we often see on damp rocks and walls and which are tough enough to grow even in the hard climate of Earth's Arctic.

To us Mars appears a pinkish colour, and except for these simple plants which come to life each year, seems to be a dead world of rocky deserts and whirling dust clouds. There may be forms of animal life in that hard, grim world, but it is doubtful. The planet does not seem to suffer either excessive heat or intense cold; it has an atmosphere, but one which is as thin as the air at the top of Everest. There does not seem to be much oxygen though there is some water. It is unlikely that any of the living things on Earth could live on Mars, and if a human being were to make a safe landing there he would not be able to live without his breathing apparatus and the compressed air which he had brought from Earth.

* * * * *

It used to be thought that Earth was the centre of the Universe and that Sun, planets and stars moved or stood still for Man's especial benefit. We know now that Earth is just a speck in space, and cannot believe that either Man or his home are of such great importance. We may never know the details of what lies beyond the SOLAR SYSTEM but probably we will soon discover a great deal more about our nearest neighbours. But this little planet No. 3—Earth—will still be worth studying for we have a great deal to learn about it yet.



Seasonal changes on Mars—left May 13, right August 20. In the right-hand picture the polar cap has vanished and the equatorial region darkened.

Seen from a satellite the Himalayas appear as insignificant as the pimples on an orange. In this drawing Earth is a ball 13 feet across.

THE SPINNING BALL

IF the scale model aeroplane is to fly it has to have an engine which bears no resemblance to the original. The water pipes in the scale model dolls' house have to be larger than the modeller would like or no water will flow through them. A scale model of the SOLAR SYSTEM would be very useful to the geography teacher for with it he would be able to show how Earth and the planets move, but unfortunately such a model would be very difficult to make and use. If Earth was a ball one inch in diameter, the Moon would be a quarter-inch bead about two feet seven inches away, and the Sun would be an eight-foot SPHERE 333 yards away.

With a globe we can study the shape of the Earth and notice the positions of mountains, rivers and seas. It would not be worth while, however, to make one of our class room globes into a true scale model of the Earth, for even the deepest places in the sea, where the five mile high Everest could be sunk and lost, would alter the globe's shape scarcely enough for our fingers to feel the bumps and hollows.

Our earth is not a perfect sphere for it is slightly flattened at the poles and bulges at the equator. Not even this distortion would show on our globe, for the diameter at the equator is only 26 miles more than the 7,900 miles through the Earth from pole to pole. On a twelve-inch class room globe this would make a difference of only 1/25 of an inch. The slight bulge is caused by CENTRIFUGAL FORCE set up as Earth's middle spins round at about 1,000 miles per hour.

Although our scale model Earth cannot show us these physical peculiarities yet it can help us to understand easily why we have night and day, winter and summer, cold poles and hot TROPICS. A candle in the middle of a darkened room can do duty for the Sun —with apologies for insulting its brilliance by such a mean light, but a scale model Sun would be as comfortable to approach as an atomic explosion! As we turn the globe we can see that one half is light and the other half is in darkness save for a shadowy twilight area where the miniature day and night meet.

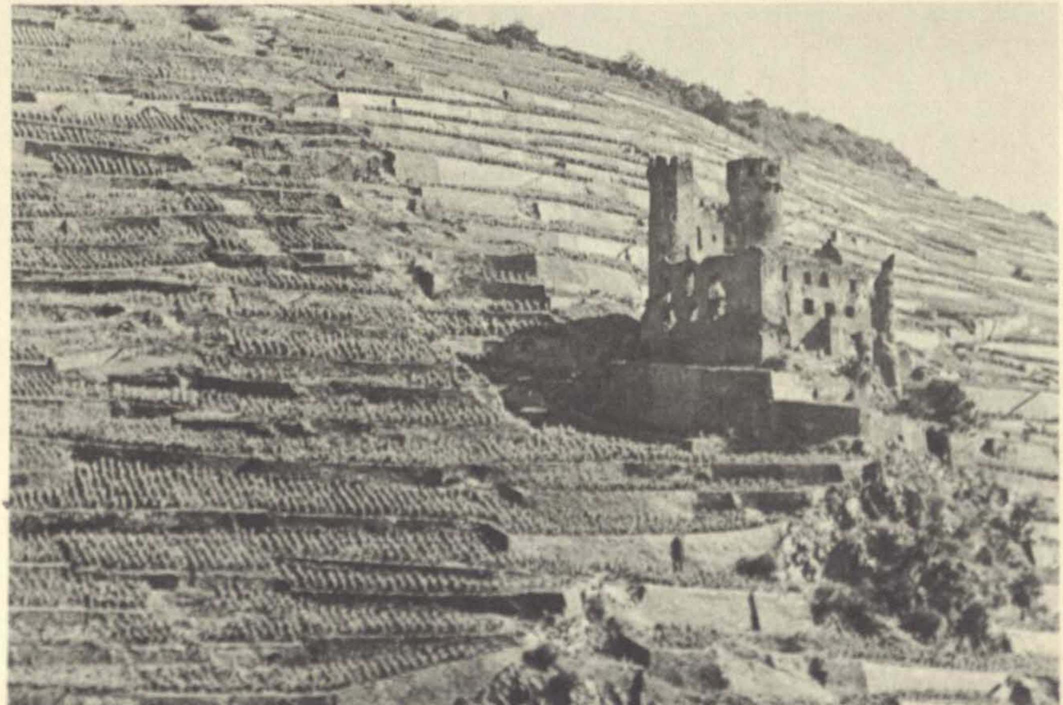
By now you will have noticed that the globe is tilted on its stand and that the South Pole is getting more light than the North Pole or *vice versa*. Arrange the globe so that it tilts towards one corner of the room and, making sure that it continues to tilt in the same direction, walk with it in a circle round the candle and notice how the darker pole grows lighter and the lighter pole darker as you move round the first half of the circle. On the second half of your walk the positions of light and shade will alter again until they become as they were when you started. This should show you how the seasons change from the midnight sun of the arctic June and antarctic December, to the darkness at noon which is felt during the polar winters. You will also see the reason for our short winter days and long light summer evenings and, if you look more closely, notice that it is not always on the equator, which we think of as the hottest and sunniest part of the world, that most of the Sun's light falls. Because, on our tilted globe, the equator appears to slope, the Sun shines more strongly sometimes above and sometimes below it. In describing positions upon Earth we must not use the words 'above' and 'below' but should say 'north' and 'south'. The regions just north and south of the equator which the Sun favours at different seasons of the year are known as the TROPICS.

Twice a year, on March 21st and September 23rd, the light of the Sun reaches both poles equally and day and night are the same length throughout the world. For this reason these dates, which we think of as the first days of spring and autumn, are called the *equinoxes* from the Latin words meaning 'equal nights'. Then at the equator the Sun is overhead and giving its greatest heat.

Between September 23rd and December 22nd the Sun appears to move southwards towards the TROPIC OF CAPRICORN. There is seems to stay for a day or two before moving northwards towards the TROPIC OF CANCER which is reaches on June 21st. The Sun appears to remain standing high in the sky for a while about these dates, which are for us the shortest and longest days. We call December 22nd the winter *solstice*, and June 21st the summer *solstice* from two Latin words which mean 'sun' and 'stand' When, it is the time of the *winter solstice* in the Northern HEMISPHERE the inhabitants of northern regions will be experiencing long dark nights, whilst those who live in South Africa South America and Australia are enjoying long sunny days; but six months later their fortunes will be reversed and the Sun will still be shining on the Shetlands when Shetland Islanders are in their beds.

The vine growers of Europe like to plant their grapes on a hillside facing south. The slope allows the plants to face the Sun squarely so that its slanting rays seem to come from directly overhead and concentrate their warmth on as small an area as possible. If you point the beam of a torch directly at the floor a small round pool of light will be formed. When the beam is slanted the pool of light becomes longer and less bright. If the torch gave off enough heat for us to measure we would find that the small, round

Vineyards in Germany on a steep hill. (Photo: Paul Popper Ltd.)



pool of light was warmer than the long and less bright pool formed by the sloping beam.

The Sun is so far away from us that its light strikes the Earth in a beam of parallel rays. At any one moment only one part of the Earth can receive those rays squarely, and as the tilted globe spins, the position of this favoured spot moves up and down (or rather to north and to south of the equator!). The rest of the globe is sloping away from the light, so that in December the northern part of the globe receives a far weaker ration of sunlight than the southern part.

From ground level where we have our homes it is not possible to see the curved surface of Earth and it is difficult to realize that, the farther we move from the equator, the more we have sloped away from the influence of the Sun. We can see, however, the position the Sun appears to take in the sky and know from experience that it is high in summer and low in winter. In the tropics a man may sometimes stand right on top of his shadow at noonday for then the Sun is overhead and is concentrating its heat upon one small area. Towards the poles the shadows are long, for the Sun is lower in the sky and its heat is spread over a larger area. By tilting their vineyards to face the Sun the grape growers give them the effect of a tropical position with the Sun overhead. But do not forget that the Sun is really always in the same place and always 'shining with all his might'; it is we who have changed our positions by staying in the same place on the 'spinning ball'.

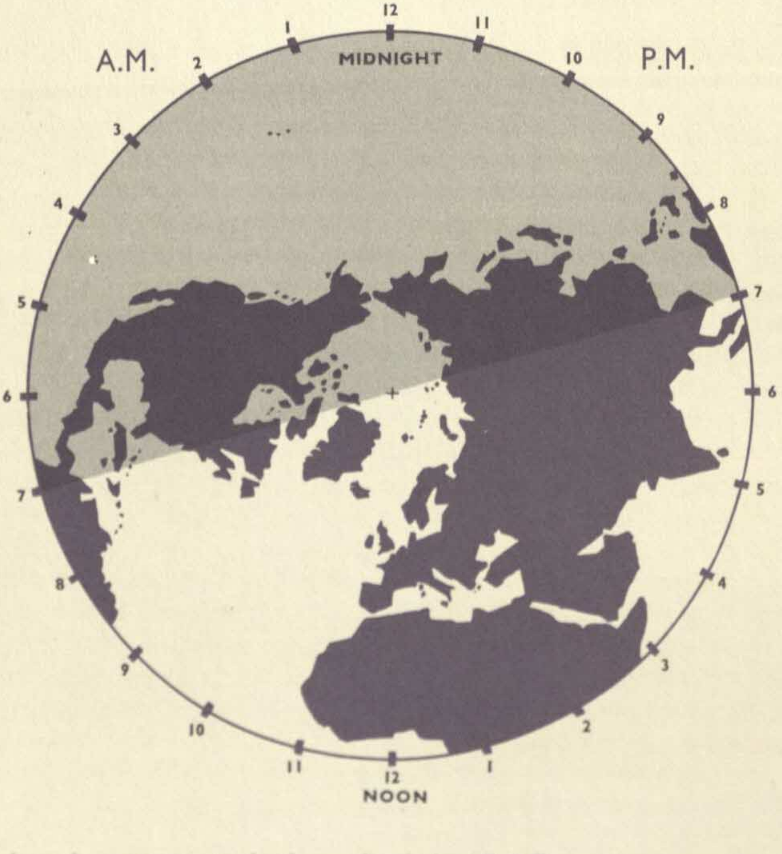
EARTH IS A CLOCK

As a wheel turns, its rim travels more quickly than a place near the hub. So it is with the world. The equator is spinning at 1,000 miles per hour but places as far away as Britain or the southern tip of South America are moving towards the east at 600 miles per hour. If an aeroplane flew due west from Britain at 600 miles per hour its speed would equal that of the spinning Earth beneath it and the pilot of that plane would see the Sun always in the same position. If he left the airport at midday the Sun would be high in the sky and the hands of the airport clock would both point to twelve. As he flew on over Canada and over Russia the clocks of people on the ground would also show 12 o'clock, yet the hands of his watch would move at their usual rate through the 24 hours. If he left on Monday and flew right round until he came home again he would arrive as the airport clocks showed noon on Tuesday. Naturally a whole day had passed, the airport workers had done a day's work and had a night's sleep, yet he had seen neither evening, night nor morning. Somewhere along his route Monday had changed into Tuesday.

Since the spinning Earth will not allow its inhabitants all to keep the same time it has been divided into time zones which follow the lines of LONGITUDE. As we know from looking at a protractor, a circle is divided into 360 degrees. An imaginary line which runs north and south through Greenwich, England, is labelled LONGITUDE 0. To east and west of this line are marked off other lines of longitude until 180 degrees east and 180 degrees west are reached. Because 180 degrees make half a circle these two lines fall exactly in the same place. Exactly opposite Britain, in the middle of the Pacific Ocean, is the line which marks the half way position on a journey round the world. As the pilot flew westwards across the Pacific the hands of his watch would be moving round towards twelve o'clock again and, if he kept his 'plane at the correct speed, he would arrive at longitude 180 exactly when his watch told him it was midnight. His airport clock on the other side of the world would be showing midnight too and those on night duty at home would realize that Tuesday had begun. Yet as the shadow of the aeroplane passed over them, passengers on an ocean liner would be enjoying the noonday sun and the cooks would be preparing the mid-day meal—lunch time on Monday if the ship was sailing westwards from America. But on an eastbound liner crossing the Pacific to Vancouver it would be Tuesday lunch time. Both ships had kept a correct count of the days since they left port yet the eastbound passengers would have to live through a second Monday; and the westbound passengers would have to do without Monday afternoon, and remember that it was now Tuesday if they were all going to know what day it was when they came to the end of their voyage.

It is fortunate that this line which causes all the trouble, the INTERNATIONAL DATE LINE, lies in the Pacific for if it were to pass through towns and villages the inhabitants would not know if it was to-day or to-morrow! Line 180 actually cuts across part of Siberia and between certain islands; but to avoid difficulties, and so that places near to each other may keep the same day of the week, the date line bends away from the MERIDIAN in some places.

The Earth turns through 360 degrees in 24 hours so it turns through one degree in four minutes. If every place in the world kept strictly to sun time there would be differences of minutes between the clocks of places only 50 or 100 miles apart. Even so small



This map shows how, at a particular hour, the clocks tell different times around the world.

a country as Britain would be affected, for the clocks of Cornwall would have to be 20 minutes behind Big Ben in London. Instead of putting the clock back four minutes for every degree we turn westwards, an alteration of one hour is made for every 15 degrees (for 15 goes into 360 24 times). Most small countries and groups of countries find it convenient to keep the time of the MERIDIAN which runs through the middle of their territories, but those countries which stretch great distances from east to west find it necessary to mark out regions where different times will be used. Europe has three time zones, the U.S.A. four, and Asiatic Russia has ten. On a journey across Australia a clock would have to be set for three different times, but one of the alterations would have to be for only half an hour, for Southern Australia and the Northern Territory form a zone in which the time is 9½ hours ahead of GREENWICH MEAN TIME. To have clocks differing by only half an hour from those in the next state is unusual and must make the task difficult for those who have to draw up trans-continental rail and airway timetables.

We may set our watches by the time signals given on the radio and we may look for the date in a calendar but it is the spinning ball of Earth which governs the days and nights and the seasons. Although he did not realize it, it was the Earth on which he stood, not the unchanging Sun, which gave primitive man his first clock.

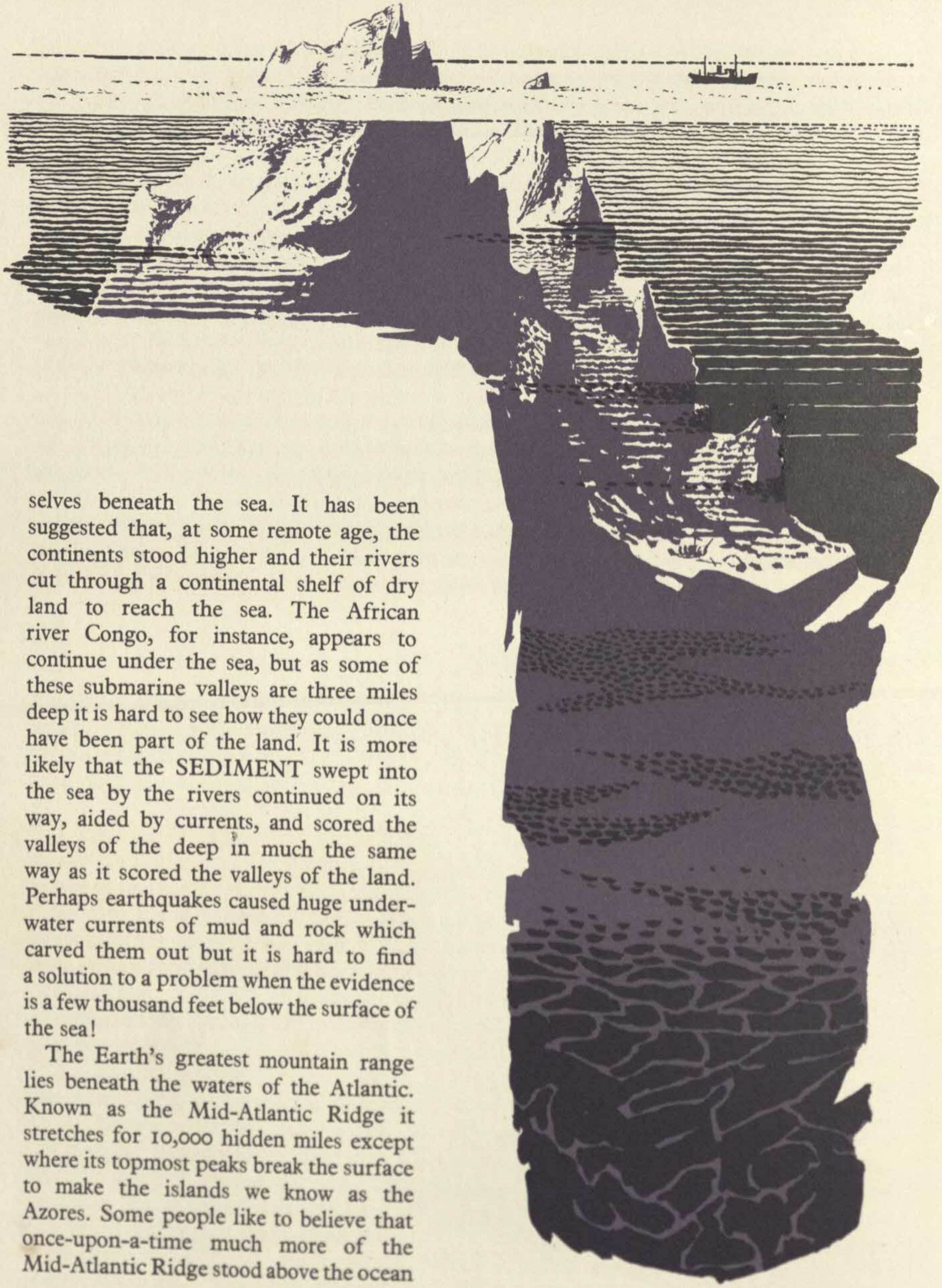
The rhythm of all Earth's creatures is controlled by the tilt of this spinning ball on which we stand.

THE WATER COVERED WORLD

MOUNT EVEREST is not the highest mountain upon Earth! True its 29,000 feet make it the highest point above sea level and the most distant place from Earth's centre, but the mountain which rises the greatest height from base to peak is Mauna Kea of Hawaii. This volcano rises 33,464 feet from the floor of the Pacific Ocean, but as more than 19,000 feet of it are below the sea we do not think of it seriously as a rival to Everest.

Three quarters of our Earth is covered by water and in that hidden three quarters are mountains and valleys far grander than anything we can see on the surface. The Colorado Cañon of the U.S.A. is a mile deep and many miles across but even this is a mere ditch compared with the great valleys of the ocean. Off the Mariana Islands and the Philippines in the Pacific are great *trenches* over six miles deep. Into either of these Everest could be dropped and still a mile of water would lie above its peak. To fill up such *trenches* and to bring all the ocean bed to the same level it would be necessary to cast all hills and mountains into the sea and carry on bull-dozing until the waters rose above us to a depth of 8,000 feet (1½ miles).

When we stand on the sea shore we see the beach sloping away from us and know that it continues to slope beneath the waves. But the sea bed does not slope forever in the same gentle fashion. Around each CONTINENT is a shelf, in some places only a few miles wide, but reaching out 800 miles to the north of Asia. In very few places is the water on the *shelf* more than 600 feet deep, but suddenly the shallow water ends and the ocean begins, for the sea bed falls off the *continental shelf* and plunges like the side of a steep hill down to a depth of several thousand feet. The faces of these great hills and cliffs are carved with deep valleys as if rivers had cut channels for them-



selves beneath the sea. It has been suggested that, at some remote age, the continents stood higher and their rivers cut through a continental shelf of dry land to reach the sea. The African river Congo, for instance, appears to continue under the sea, but as some of these submarine valleys are three miles deep it is hard to see how they could once have been part of the land. It is more likely that the SEDIMENT swept into the sea by the rivers continued on its way, aided by currents, and scored the valleys of the deep in much the same way as it scored the valleys of the land. Perhaps earthquakes caused huge underwater currents of mud and rock which carved them out but it is hard to find a solution to a problem when the evidence is a few thousand feet below the surface of the sea!

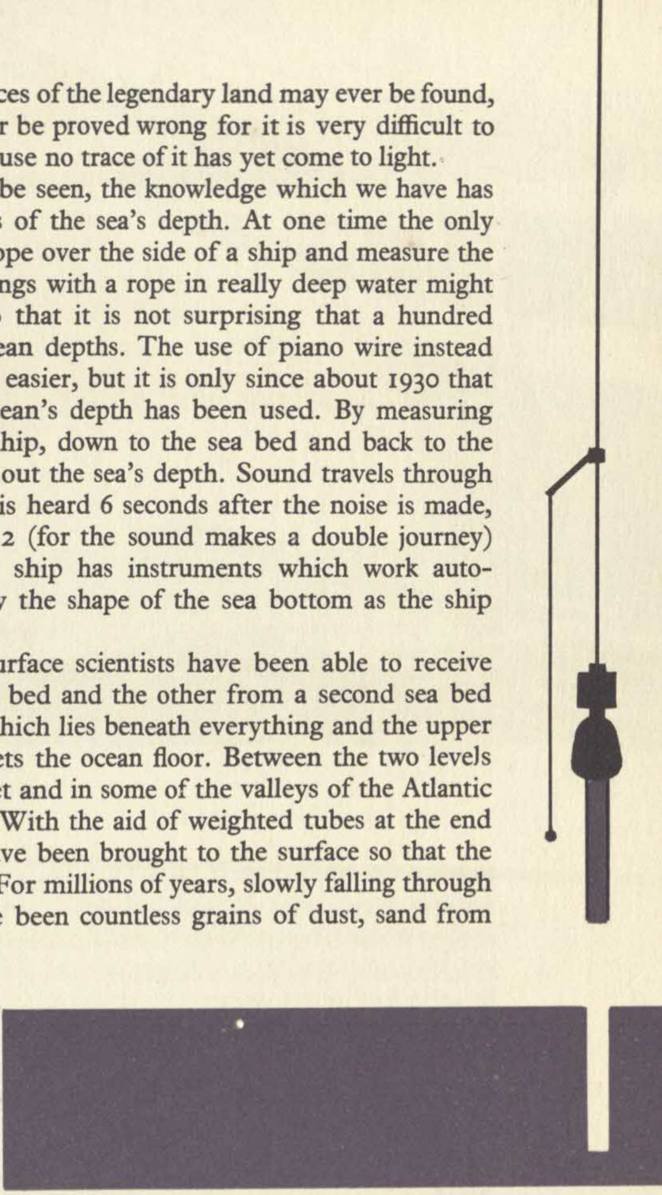
The Earth's greatest mountain range lies beneath the waters of the Atlantic. Known as the Mid-Atlantic Ridge it stretches for 10,000 hidden miles except where its topmost peaks break the surface to make the islands we know as the Azores. Some people like to believe that once-upon-a-time much more of the Mid-Atlantic Ridge stood above the ocean

Some of the world's greatest mountains lie beneath the sea. The islands which are visible may be only the mountain peaks.

to form the fabled land of ATLANTIS. No traces of the legendary land may ever be found, but those who believe in it will probably never be proved wrong for it is very difficult to prove that something did not exist simply because no trace of it has yet come to light.

Since the pattern of the ocean floor cannot be seen, the knowledge which we have has been gained from thousands of measurements of the sea's depth. At one time the only way of making these was to drop a weighted rope over the side of a ship and measure the FATHOMS as they ran out. To make soundings with a rope in really deep water might take a ship's crew the best part of a day so that it is not surprising that a hundred years ago very little was known about the ocean depths. The use of piano wire instead of rope made the task of measuring somewhat easier, but it is only since about 1930 that a quick and simple method of finding the ocean's depth has been used. By measuring the time taken for a sound to travel from a ship, down to the sea bed and back to the ship again, it is a fairly simple matter to work out the sea's depth. Sound travels through water at 4,800 feet per second, so if the echo is heard 6 seconds after the noise is made, the depth of the water will be 4,800 × 6 ÷ 2 (for the sound makes a double journey) which equals 14,400 feet. A modern survey ship has instruments which work automatically and draw a continuous line to show the shape of the sea bottom as the ship steams onward.

By exploding depth charges beneath the surface scientists have been able to receive two echoes; one of which comes from the sea bed and the other from a second sea bed below that. The lower level is the solid rock which lies beneath everything and the upper level is the top of a layer of ooze which carpets the ocean floor. Between the two levels there is in places a difference of a thousand feet and in some of the valleys of the Atlantic floor there is a layer of ooze 2,000 feet thick. With the aid of weighted tubes at the end of long cables, samples of the top fifty feet have been brought to the surface so that the stuff which makes up the sea bed can be seen. For millions of years, slowly falling through the water like snowflakes upon the land, have been countless grains of dust, sand from the world's shores and minute sea creatures.



The core-sampler is lowered to the sea bed, the weight drives it into the ooze and a sample is brought up to the surface.

THE MOVING WATERS

A BOTTLE of sea water would be to most of us nothing more than a bottle of very salt water, but to the OCEANOGRAPHER it may be a piece in a vast jig-saw puzzle. From the sides of research ships bottles have been let down into the sea and samples of the water have been brought up. The temperature of the water has been recorded, the amount of salt dissolved in it measured and the number of tiny creatures it contains counted. From these facts the oceanographer has learned of the movements of the waters, of the warm and cold currents and what causes them, and the effect they have on life in the sea.

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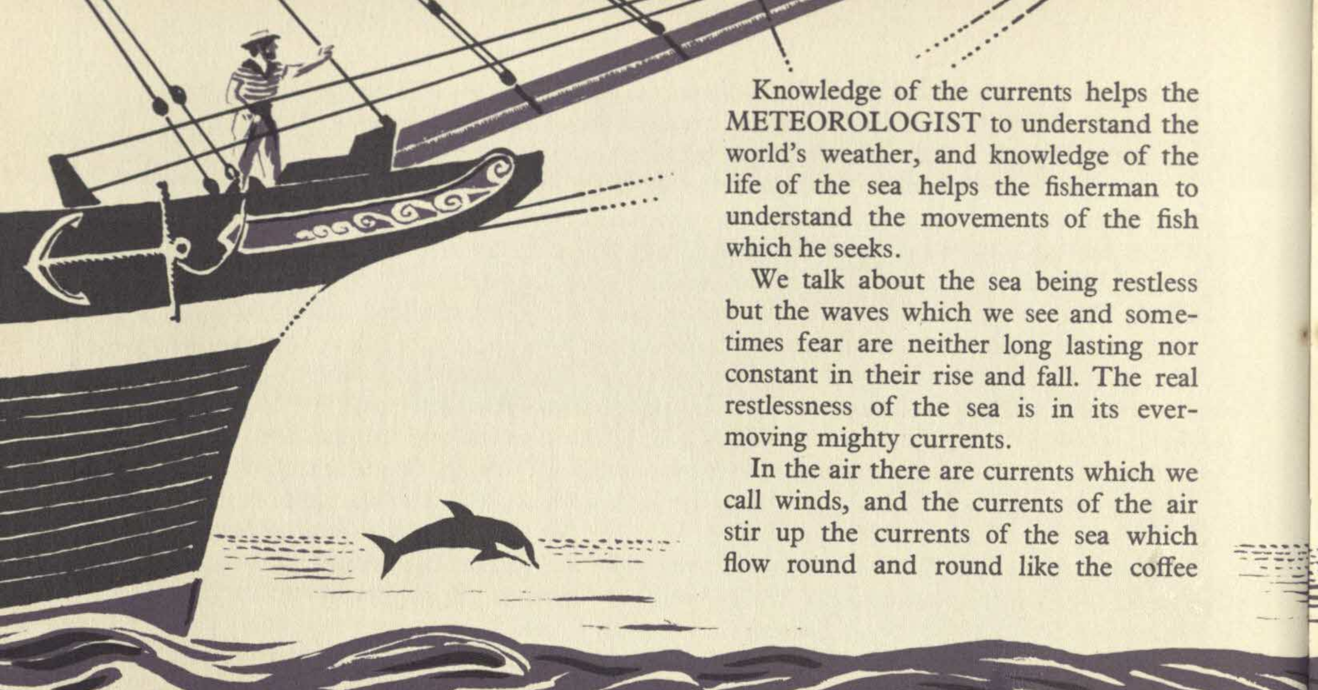


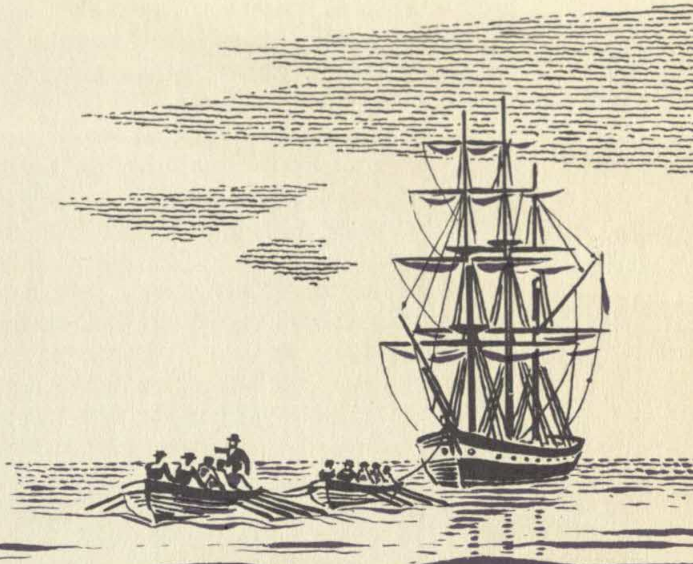
Knowledge of the currents helps the METEOROLOGIST to understand the world's weather, and knowledge of the life of the sea helps the fisherman to understand the movements of the fish which he seeks.

We talk about the sea being restless but the waves which we see and sometimes fear are neither long lasting nor constant in their rise and fall. The real restlessness of the sea is in its ever-moving mighty currents.

In the air there are currents which we call winds, and the currents of the air stir up the currents of the sea which flow round and round like the coffee

Ships make use of the ocean currents to help them on their way. Here a becalmed sailing ship is being pulled from still water into the swift current.

in your cup when you blow upon it at an angle. From the north-east and the south-east towards the equator blow winds which we call the TRADES. The trade winds take the surface waters of the Atlantic and Pacific and carry them westwards. Although the waters are free to move they still are part of Earth, and the sea currents show that they feel the effect of being part of a 'spinning ball' by moving to the right (clockwise) north of the equator and to the left (anti-clockwise) south of the equator. So it is that the currents of the Northern HEMISPHERE swing to the north and then to the east wheras those of the Southern HEMISPHERE swing to the south and east. The North Equatorial Current of the Atlantic raises the water in the semi-circular Gulf of Mexico to several feet above the level of the neighbouring ocean. (So the sea is not as level as it appears, but in some directions slopes gently uphill where the currents have piled up the waters.) The warm current from the equator cannot enter the Gulf of Mexico but, as it has to flow somewhere, it makes a sharp right-hand turn and pours to freedom through the narrow 40 mile gap between Cuba and Florida. A person standing on the eastern shore of Florida would see the sea rushing past him at six miles per hour so that it looked like a great river. It would be almost correct to call it a river of the sea (a huge one which carries 1,200 times as much water as the Mississippi) for it is possible to follow it along the coast of the U.S.A. and across the Atlantic to the shores of Europe. It has no banks but it has edges, and ships which sail upon it travel faster than those which sail upon the rest of the ocean. The warm waters which this current, the *Gulf Stream*, sends to the shores of Europe help to give Britain, France and neighbouring countries a milder climate than they would otherwise enjoy. Much of the coast of Labrador is no farther north than Britain yet no one would expect Britain to have to endure the same sort of winter as Labrador with its average of 32 degrees of frost. Labrador and Greenland are both well known for their cold climates and both are bathed by currents which flow southwards from the Arctic Ocean. If a giant could build dams and sluices so that the direction of these currents could be changed, and could also turn the winds towards the west, spring would come early to Labrador and fruits would grow in orchards in Greenland, but the coasts of Europe would be icebound for many months of the year, trade would come to a standstill and our civilization would die.



Yet if we bathe in the waters of the Gulf Stream Drift they do not seem to us to be particularly hot. The temperature of the sea needs to rise by only a few degrees for the air above it to be warmed too. To warm our rooms with central heating radiators the water in them needs to be very hot, but that is because we are causing a large volume of air to be warmed by a small amount of water. The water of the ocean, on the other hand, is so plentiful that it has a smaller task to do than the water in the central heating system. The ocean stores heat and carries it from one part of the world to another. It helps to cool the hot lands and warms the areas which are not so favoured by the Sun.

Winds start some of the ocean currents on their way and the air which passes over the warm currents becomes in its turn a wind which may bring some of the warmth of the tropics to a cold distant land.

Currents can also be caused by differences in the weight of water. In the Mediterranean Sea more water is lost by evaporation than is gained from the rain or from rivers. As sea water evaporates salt is left behind so that the water in this large basin becomes more salty than water in cooler seas or where a greater quantity of rain falls. The heavy, salty water sinks and flows out into the Atlantic whilst above it the lighter ocean water flows into the Mediterranean. So it is that at the straits of Gibraltar there are two currents flowing in opposite directions in the same place. An ocean liner is helped into the Mediterranean by one current whilst at 1,200 feet the out flowing current is so strong that instruments sent down to measure it have been broken as they were swept against rocks like sticks in a mountain stream.

During the INTERNATIONAL GEOPHYSICAL YEAR oceanographers discovered a huge underwater current, as big as the *Gulf Stream*, flowing eastwards for 3,500 miles through the Pacific Ocean. Several hundred feet below the surface a mighty river is flowing at a rate of 27 miles per day in the *opposite direction* to the current which carried the famous raft KON TIKI.

The currents of the ocean flow steadily at the surface and in the depths, but the tides come and go and cause the surface of the sea to rise and fall twice every day in most parts of the world. The cause of the tides is the Moon for the Moon is tugging at the Earth, but as its pull of GRAVITY is so much less it is only able to pull feebly at its parent Earth and disarrange her clothes. The water is free to move over Earth's surface and so it tries to pile up where it feels most strongly the pull of the Moon. The Sun joins in this strange tug of war too, but although the Sun is many times bigger and stronger than the Moon it is so far away that its effect is much less. When Sun, Moon and Earth are in line as they are once a fortnight, at the times when we see a new or a full moon, the tides are high for then Sun and Moon are pulling in the same direction. Such high tides, when the sea comes in and goes out farther than usual, are called SPRING tides.

When Sun and Moon are pulling at right angles, as they do when the Moon shows us only half its disk, they nearly cancel each other out; but usually the Moon wins the contest and causes small tides which also happen once a fortnight and are called 'neap' tides. Although there is only one movement of the waters every day we see two tides, for when it is high tide with us it is also high tide at the ANTIPODES, and as the Earth turns once in every day we meet the great wave twice as we turn. When we are at the sea side we usually notice that the high tide arrives nearly an hour later each day. The delay is really 50 minutes and is caused by Moon moving ahead on its journey round Earth whilst Earth makes one of its daily turns. Each day Earth is 50 minutes later in catching up with the Moon.

Many things affect the height of the water which laps our shores. The tides are made in the Southern Ocean where waves can travel round and round the world from west to east without ever being interrupted. There the height of the tide is affected only by Sun and Moon and it probably rises no more than a foot or two. But the great wave enters other oceans and rushes through them—travelling the length of the Atlantic in only one day—and flowing on until it enters every bay and inlet, each narrow channel and shallow basin. In shallow water the tide travels more slowly and usually builds itself up to a greater height than in the ocean. The depth of the sea and the shape of the land surrounding it affect the height of the tides in ways which scientists are gradually beginning to understand. The Mediterranean Sea is almost tideless, at Tahiti the height of the tide is only a foot, but in the Bay of Fundy between Nova Scotia and New Brunswick the water is bottled up and forced to a great height. Like soup in an unsteady bowl the water in this bay rocks to and fro and helps the great tide to rise and fall more than 50 feet on the Nova Scotia shore at Burncoat Head. At Mont St. Michel in France the slope of the shore is so gentle that the sea retreats for miles leaving the ancient town high and dry. When the tide comes in again it races over the sand at the speed of a galloping horse so that anyone who has foolishly walked far from the island is in danger of being caught.

Tides are waves that sweep around the world regularly so that their arrival and even their height may be forecast fairly accurately. But the waves which we see breaking upon our shores may vary from day to day for they are caused by winds, perhaps by storms some hundreds of miles away.

So great are the tides in the Bay of Fundy that, at high water, the sea sweeps over the fishermen's nets. (By courtesy of the High Commissioner for Canada.)

Waves cannot grow to great heights until they have travelled far across open water with a strong wind behind them. The largest waves ever experienced by sailors have been in the Pacific where gales sometimes blow for days and where waves may have a *fetch* of 4,000 or 5,000 miles. Although sailors love to tell of seas 'mountain high', not many waves are more than 25 feet—the height of a small house—from trough to crest. Nevertheless waves 60 feet in height have been seen and once in the Pacific an officer of A U.S. ship claimed that one 112 feet high towered above him as his ship lay in a trough.

To us as we watch the waves rolling in the whole surface of the sea appears to be moving, but this is not so; the waves do not form currents. They travel through the sea and the water in them rises, falls and turns in a circular pattern. If you throw a stick into the waves you see that it is carried forward very little but that it moves up and down as the waves appear to slide underneath. If the stick was thrown into a current it would be carried forward at the same speed as the water.

When a wave comes near the shore the revolving particles of water of which it is made are slowed down at the bottom, it grows taller and narrower and its crest rushes forward to topple over and foam upon the sand. Its journey is over but far out in the ocean a storm may be raising waves which we will see to-morrow; a tide which will only reach our high water mark in the middle of to-morrow night is even now lifting in the endless Southern Ocean; and the currents, both at the surface and in the depths, are transporting the warm or cold waters which help to make our climate what it is.

From the volcano's gaping mouth the molten rocks of the underworld have poured to form this strange island. (Photo: Paul Popper Ltd.)

"JOURNEY TO THE CENTRE OF THE EARTH"

... is the title of a story written by Jules Verne, one of the earliest science-fiction writers, about 100 years ago. Of course no one has been able to make the terrible journey which he imagined, but for all that scientists have been able to find out a great deal about what the inside of the Earth is like. The distance from the surface to the Earth's centre is over 3,950 miles but man is only able to explore the top few thousand feet of the crust. If Earth was the size of an apple the deepest mines and oil wells would not even puncture the apple's skin. Yet even such tiny punctures as are made by deep mines show that for every thousand feet we dig down the temperature rises by 15 degrees Fahrenheit. At this rate the temperature at the bottom of the Champion Reef Gold Mine, Mysore, India—10,144 feet below the surface, must be over 150 degrees Fahrenheit so that air conditioning has had to be installed to keep the miners from being roasted. If the mine went down another 1,400 feet there would be a risk of the tunnel walls bursting as the rocks would then be slightly softened by the heat.

Two and a half miles down, the boiling point of water is reached, so this is probably the depth to which some rain water sinks for it to boil and make the clouds of steam which burst through the surface again as a geyser. Thirty-one miles from the surface it begins to be hot enough to melt rock (2,200-3,300 degrees F.). This is the region which is responsible for volcanoes for the molten rock is, in some places, able to force its way up through cracks in Earth's crust.

If the temperature continued to rise in this way the centre of the Earth would be at 300,000 degrees F.; but below the Earth's crust the increase is much slower, so that Earth's core is probably about as hot as the surface of the Sun (10,800 degrees F.). At this temperature of course nothing should remain solid and the core is thought to be a ball of molten nickel and iron 4,300 miles in diameter. To describe Earth's core it is necessary to contradict oneself; it is molten, yet solid; liquid, yet it cannot flow as a liquid should. The rocks around the core press with a weight of 23,000 tons on every square inch and it is this enormous pressure which upsets our ideas about how liquids should behave. We must try to think of Earth's centre as a molten plastic mass which is so tightly compressed that it is more like a solid than a liquid.

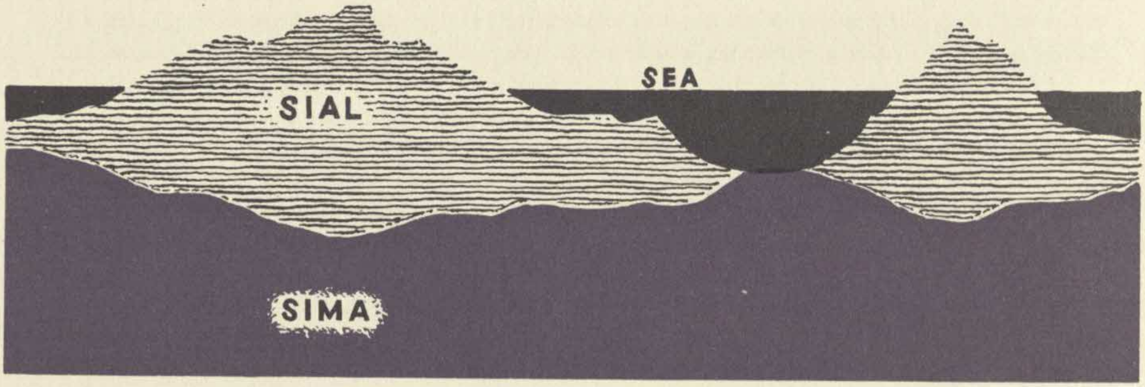
As when astronomers measure the stars no instruments can be sent to find out the truth, and most of the discovery is done with pencil and paper, working with figures which are supplied by instruments at Earth's surface. Information about the stars is supplied by waves of light which come from the stars themselves. Information about Earth's interior comes from waves supplied by Earth—not light waves this time—but shock waves which come from Man's dreaded enemy the earthquake. Naturally no GEOPHYSICIST wants earthquakes to happen and destroy buildings and cities, but every time there is an earthquake he is able to make use of it by noticing the facts which his SEISMOGRAPH tells him.

An earthquake sends out two kinds of shock waves which we call *push* waves and *shake* waves (P. and S. WAVES). They move at different speeds and, although *push waves* will travel through solids and liquids, the *shake waves* will travel through solids only. Imagine a long queue of people standing relaxed quite close to each other. If some mischievious passer-by gave the tail-end person a shove, the next one in line would lurch forward before recovering himself and pass the shock on to the one in front. The first person in the queue would probably fall right over though he would be a long way from the beginning of the *push wave*. A *push wave* then would travel through a line of people but a *shake wave* would not, for if the last person in the queue decided to amuse himself by singing and swaying from side to side, those waiting with him would be more likely to tell him to go home than join with him! Because they will not pass on the *shake wave* the people are rather like a liquid.

A *shake wave* can, however, be made by two people holding a rope between them. If one wriggles it, little ripples seem to run from one end to the other.

All over the world there are SEISMOGRAPHS which show how strong the shock waves are, from which direction they come and how long they take to arrive. Suppose there is an earthquake in Japan—as often happens—then seismographs in Brazil will show P. WAVES but no S. WAVES coming through the centre of the Earth. Therefore, say the geophysicists, there must be something liquid at the centre of the Earth. Waves travel more quickly through heavy than through light materials; so further study of the shock waves, the paths they travel and the time they take in getting to dozens of different places on Earth's surface show the scientists that the Earth is made of layers of materials of different weight.

Since the seismographs show that there is something liquid at Earth's centre we must imagine a core of rigid molten nickel and iron. Around this is a mantle of heavy metallic rocks, then a layer known as the SIMA which consists of rocks like basalt. In some of the ocean depths the SIMA may form the crust of the Earth for we cannot be sure whether the outer layer, known as the SIAL, covers all the deep ocean bottoms or not. The SIAL consists chiefly of rocks such as granite which make up the continents. In places the layer of SIAL may be 20 or 30 miles deep, but it is hard to measure anything so thin when man is too small to bore through it and when the only way of measuring it is by calculating the speed of earthquake waves! The SIAL is like the skin of



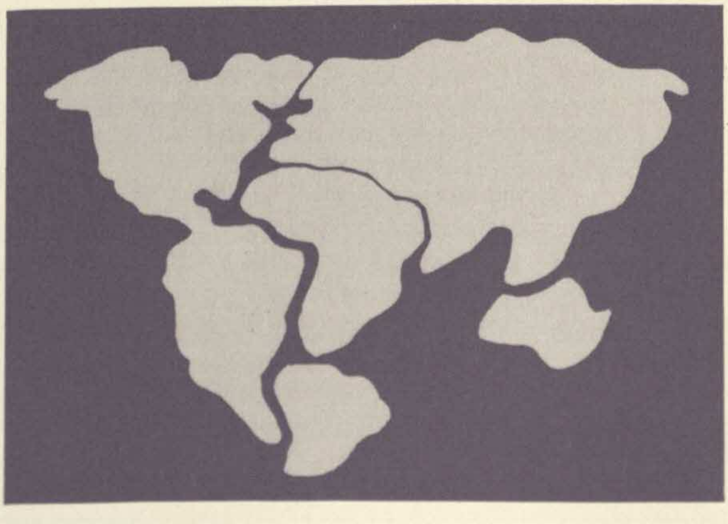
The continents may be like islands floating upon the plastic rocks of the Earth's mantle.

an apple but the apple has splashes of dirt on it from lying on the ground. This dirt which wipes off so easily stands for the rocks which we see, the soil in our fields, the sand of the deserts, the mud of the river, the clay, the gravel and even the chalk hills.

There may be a portion of the SIAL even farther away from the Earth's centre than is its rocky crust. Some think that the Moon, a child of the Earth, was born when Earth was young and before her rocks had become completely solid. It is thought that a layer of SIAL gathered itself together and became separated from the Earth, rolling itself into a ball as it did so. This was the Moon which did not fly off into space but remained tied to the Earth by GRAVITY. The rocks which formed the Moon robbed the Earth and left a hollow. When the first rain fell this hollow filled with water and formed the ocean which we know as the Pacific. This idea may be the truth for there does not seem to be any granite type rocks in the Pacific and it is thought that the Pacific's floor is the deep hidden SIMA rather than the visible SIAL.

We sometimes use the expression 'as hard as a rock' for it is difficult to think of anything harder, yet the hard basalt of the SIMA seems to be plastic under the weight of the continents—great blocks of SIAL—which rest upon it. A pound of butter standing on a plate in a cool larder is fairly solid and must seem as hard as rock to a fly landing upon it, yet if you had a ton of butter (which would stand about 7 feet 6 inches high on a slab 3 feet by 2 feet) the bottom part would be squeezed outwards and the solid butter would begin to flow all round its slab and on to the floor. True, the rocks on which the continents lie are not made of butter, but neither is the weight which they bear as little as a ton. With millions of tons pressing down on them the rocks of the SIMA are made to flow as the metal in a penny flows into a new shape when it has been placed on a railway line for a train to run over. Ice floats on water because it is lighter; so, it is thought, the continents float like rafts on the heavier SIMA which lies beneath them. An iceberg has a huge keel of ice below the surface of the sea, and in the same way the mountains have keels or roots which go deep down into the SIMA below them. If the top of an iceberg was cut off it would float higher in the water and if a load of fresh ice was dumped on top it would sink lower. The same thing is thought to have happened with the continents; when mountains have arisen the continental rafts have sunk under their weight, and as the mountains have been worn down the rafts have risen higher from their bed. This sort of thing has happened many times during the 7,000 million years of Earth's history. Usually the up and down movements were slow—perhaps a foot in a hundred years—but that is quite enough to lift into hills, rocks which had been formed beneath the sea and which contained the FOSSILS of long dead sea creatures. It is also fast enough for the land to sink so that the sea flows over it, or for cracks to develop and great masses of rock to sink below the neighbouring land to form steep sided *rift valleys* such as the valley of the River Jordan.

If we can think of the continents as floating rafts it is not difficult to imagine that they could move to and fro upon a sea of SIMA. This idea which is called the THEORY OF CONTINENTAL DRIFT has been argued about for over 40 years. It is suggested that at one time all the continents were gathered in one great mass of SIAL surrounding the present land of Africa. This is quite likely, if we believe that the hollow we call the Pacific was caused by the birth of the Moon. We are told that rifts appeared in the SIAL and that, obeying some great force, the continents began to drift apart and take up their present positions. A jury weighs up the evidence of a prisoner's guilt, and the jury of GEOPHYSICISTS who try to decide about the theory of *Continental Drift* are asked to consider three important pieces of evidence. One is that if we made cardboard outlines of the continents we could fit them fairly well together like a large rather badly made jig-saw puzzle. The bulge of South America fits fairly well into the curve of the western coast of Central Africa. Secondly GEOLOGISTS tell us that very old mountain ranges of identical pattern and containing similar rocks are found on both sides of the Atlantic so that they might well have been all one chain before the drift began. For example—the Appalachian Mountains of North America appear to



The continents may once have fitted together like pieces of a badly made jig-saw puzzle.

be continued in the Caledonian Mountains of Scotland and the mountains of Norway. The third bit of evidence is that coal, in which may be found the fossils of prehistoric tree ferns, has been found in Antarctica and in the cold northern island of Spitzbergen. Could it be that once, in the age of coal forests 250 million years ago, these desolate places were closer to the equator and were part of a large continent warm enough for tropical plants to flourish?

For us it is easier to understand the evidence in favour than the evidence against the drift idea, for those who argue against it have to prove that it could not have happened because the force which is supposed to have separated the continents could not have been strong enough. It is, of course, difficult to prove such a thing for not enough facts are known, and the mathematics needed for the proof would be very complicated. It is only fair to say that such an idea is worth considering; it may be true. We cannot even say with certainty what the lower regions of Earth are like to-day so we can hardly be expected to understand what they were like hundreds of millions of years ago!

JUST BENEATH OUR FEET

WE are driving through the countryside and watching the scenery. Here are cows browsing in the rich meadow grass by the side of a gently flowing river; farther on amongst the hills are small fields of short grass surrounded by stone walls instead of hedges. In one place there is a beech wood and in another a stretch of open country covered with gorse bushes and bracken. One village consists of brick built houses and another has cottages of stone.

Most of the changes which we see are brought about by the rocks—not the granite or the basalt of the Earth's interior, but by 'the dirt on the skin of the apple'—the rocks beneath our feet. Not all rocks are hard and rough and cold like those we see in the cliffs of the sea shore or on the side of a barren mountain. GEOLOGISTS call most of the solids of Earth's crust rocks whether they are hard or soft, wet or dry, rough or smooth.

Before the days of steel girders, reinforced concrete, sheet glass and aluminium; when transport was difficult and expensive Man made his houses and churches, or enclosed his fields with the materials which came easiest to hand. Where outcrops of stone lay all around him and when he had to shift boulders before he could plough it was natural that he should build both houses and fences of stone. Those who lived on the chalk, being short of stone, found flints in the chalk and used them for their churches.

The wiry fescue grass of the limestone and chalk hills makes excellent sheep pasture and is enjoyed by rabbits which nibble it to a fine turf. On the sand and gravel of the heath little can grow but heather and bilberry. The soil the farmer likes best is the loam which contains more clay and silt than sand. Where such soil is found there will be prosperous farmlands.

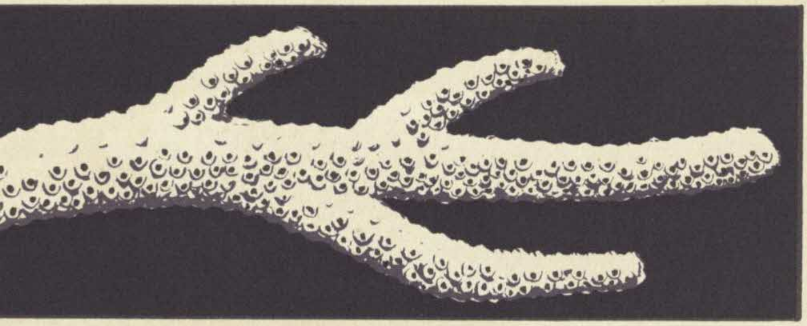
Trees too can be a pointer to the type of rock on which they grow. Oaks flourish upon clay whereas pine trees are more usually found on sandy soil and beechwoods upon the sides of chalk hills.

A map showing the SURFACE GEOLOGY of the area where we live helps us to

Limestone rock is responsible for the scenery of the Yorkshire dales. There are plenty of stones for building but fields are not suitable for ploughing nor do many trees grow on the hillsides. (Photo: Paul Popper Ltd.)

understand why it is that trees grow better in some places than in others or why a farmer uses his fields in the way he does. On maps of this type the key will show, in many different colours, rocks with such names as *London clay* or *Bagshot sands* (so named after the places where the best examples are found) and *alluvium* or *plateau gravel*. These form the topmost layer of all, but in a good atlas you may see a map of SOLID GEOLOGY showing the older rocks lying underneath the gravels and sands. Such rocks give a country its shape and character though they may seldom be seen by the person walking across the surface of the land. The *oolitic limestone* gives Britain the warm beauties of the Cotswolds just as the *carboniferous limestone* and *millstone grit* are responsible for the stern grandeur of the Pennines.

GEOLOGISTS divide all rocks into three main classes to which they give the names IGNEOUS, SEDIMENTARY and METAMORPHIC. The first of these are the rocks which were melted in fire, in the great heat of the Earth's interior, and which became solid when they cooled. The oldest of rocks are IGNEOUS, formed in the days when Earth was cooling, but there are rocks of this type being formed to-day. Every time a volcano erupts a stream of molten *lava* pours down its sides. This cools quickly in the air and sets in a smooth glassy form such as *obsidian*. The *pumice stone* which we find so useful for cleaning dirty hands is also a form of *lava* but which has received its appearance from the bubbles of gas which it contained when molten. If the molten rock, forcing its way upwards between the cracks in Earth's crust, does not manage to reach the surface it cools much more slowly so that crystals form in it. Such rocks are *granite* and *diorite* which may sometimes be found at the surface to-day for the rocks which once lay above them have been worn away by the weather of a million years. There are many members of the family of IGNEOUS rocks, all different from one another because of the chemical



An island sank beneath the sea but a ring of coral has continued to grow round its rim to form an atoll. The branch of coral is the material of which reefs are built.

make-up of the deep seated rocks from which they were formed or because of the conditions under which they cooled; so that IGNEOUS rock from the ocean floor (for volcanoes erupt in the depths as well as on land) will be very different from a piece of pumice stone or a slab of granite from a mountain side.

Rock is broken up and worn away by the action of the weather, but that which is taken away from the hills is not lost to the Earth for it is deposited on the plains or dissolved in the sea. These rocks which are laid down like carpets upon the land or upon the sea bed are known as SEDIMENTARY. Through millions of years the layers have formed one upon the other, in the sea, in rivers, at the sides and feet of glaciers or on the plains where dust has been blown by the wind. As the deposits grew thicker their weight increased and the lower layers became compressed and solid. *Sandstone* is made up of countless grains of sand cemented together by substances dissolved in the water which filtered through them. *Shale* is a fragile, flaky rock made of layers of rock which have been pressed together. We sometimes find stones which we call 'pudding stones' but whose real name is *conglomerate*. These were formed when pebbles and sand were deposited together and squeezed into a mass resembling a rich pudding.

Coal is a SEDIMENTARY rock formed of compressed tree ferns in the marshes of 250 million years ago. A mere 100 million years ago the white cliffs of Dover and the *chalk* hills of Southern England were being formed at the bottom of the sea as innumerable tiny sea creatures lived, died and drifted down upon each other so that their skeletons piled up into a layer of rocks 300 to 400 feet thick. Later the land rose, the sea fell back and the chalk was left high and dry for soil to form and grass to grow upon it.

The chalk is old and a permanent part of our scenery but rocks are still being made out of the tiny skeletons of the CORAL POLYPS which live in the warm shallow waters of sunlit tropical seas. They anchor themselves to a solid rock and live and die in the same place to become a solid basis on which the next generation of polyps fasten themselves in their turn. Although *coral* cannot grow in water more than 150 feet deep some of the coral rocks go down into the sea more than 1,000 feet, for during the time that they have been building, the floor of the sea has been sinking beneath them. The polyps cannot live out of water either and once they have reached the surface of the sea they

die; bits of coral break off, the waves grind them to sand and pile them up until a small island is formed. Once the island has reached a sufficient distance above the water it is ready to accept whatever the wind and waves bring it. Coconuts and mangrove seeds float ashore and sprout, birds leave droppings containing seeds, and seeds borne by ocean winds fall on to the coral sand. Plants grow and their roots help to bind the surface of the island together. They die, decay and help to form the soil in which other seeds may take root.

The tiny CORAL POLYPS are responsible for the Great Barrier Reef of Australia which stretches like a breakwater for 1,260 miles along the north-east coast of Australia. Most of the reef lies beneath the surface of the water and is a danger to any ship which does not have a skilful pilot aboard; but here and there an island has appeared and become the home of thousands of sea birds which have such names as Noddy terns, boobies and mutton birds!

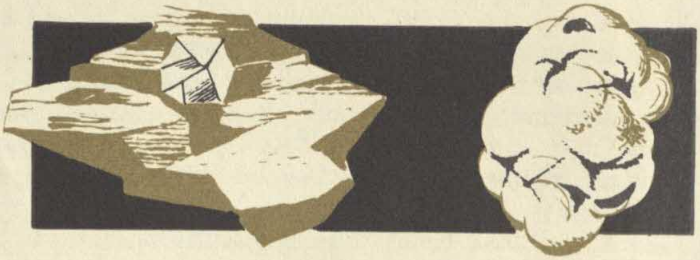
When the frog in the fairy story is turned into a handsome young prince he is said to have undergone a *metamorphosis*; this means that he has been changed, and the METAMORPHIC rocks are those which have been changed from what they were originally into new forms. The bricks of which we build our houses are man-made METAMORPHIC rocks, for the clay in them has been pressed and baked into something hard like stone. Man used heat to make bricks and Nature has often used heat to make her metamorphic rocks.

Sometimes the heat was supplied by a mass of molten rock forcing its way up amongst the surface rocks. As it cooled to form an IGNEOUS rock its heat travelled outwards for several miles changing the form and appearance of surrounding SEDIMENTARY rocks. *Limestone* was thus sometimes changed into *marble*, and *sandstone* into the tough shiny *quartzite*. Sometimes a large area of land would be buried or folded so that rocks which once were near the surface sank to a depth of 10 miles or so. Then the enormous pressure and heat would combine to change *granite* into *gneiss*, and *shale* into *slate* or *mica schist* with its shiny flakes. Here in the depths of Earth's crust is a wonderful laboratory where dull *oxides* of *aluminium* and of *copper* have been changed into sparkling *rubies*, *sapphires* and *emeralds*.

The whole of the crust of the Earth is being changed by the wash of rain, the heat of the Sun, the splintering cold of the frost and by the wind which whips away loose grains to drop them elsewhere. Acids dissolved in the rainwater filter through the ground and play their part in changing the appearance of the rocks. Every alteration which has taken place in the rocks beneath our feet has helped to shape the lives of the creatures which make their homes and seek their food upon Earth's surface. Man's work, his buildings, his food are all affected by the rocks on which he lives—by the granite with which he makes his public buildings, the limestone houses, and his palaces decorated with marble. The quality of the soil affects his crops and the animals which graze in his fields. His industries rely upon the coal and mineral ores which lie beneath his feet.

The study of these rocks, the science of geology, is very important in the modern world. Engineers must know something of geology before erecting skyscrapers, building bridges or digging tunnels. Miners and those who drill for oil depend upon a knowledge of geology for their very living.

Although they form such a small part of the Earth it is probably wrong to speak of the surface rocks as 'the dirt on the skin of the apple'—an apple would still be an apple without its dirt, but the Earth would be barren and dead without its covering of surface rocks.



Two gem stones formed deep beneath Earth's surface. The diamond consists of carbon and is found embedded in a rock called Kimberite. The bluish-green turquoise contains copper and aluminium.

THE HANDS OF A GIANT

HIGH up in the Andes mountains of South America is a statue of Jesus with these words engraved upon it: 'Sooner shall these mountains crumble to dust than shall the people of Argentina and of Chile break the peace which ... they have sworn to maintain' The life of man is short and even his strongest buildings fall to pieces within a few thousand years. It is no wonder that we speak of the 'eternal hills' and look upon them as permanent features of Earth's surface, for Man has been an inhabitant of his world for less than 1,000,000 years. Yet even those mighty peaks of the Andes are young in the history of the Earth, being much less than 60,000,000 years old.

The oldest mountains of all have long since disappeared for they have been worn away until only their roots of hard old rock remain.

Earth's noblest mountain ranges, the Alps, Himalayas, Rockies and Andes all started life as deep basins known to geologists as GEOSYNCLINES. In one such dip in the Earth's crust between what are now the continents of Africa and Europe there was once a sea longer and wider than the present Mediterranean. Through millions of years the sea deposited its mud and sand, and tiny sea creatures fell to carpet the sea bed until this geosyncline became filled with a band of SEDIMENTARY rocks about 700 miles wide. Then the great folding began; first wrinkles appeared in the surface, then folds which lifted into a fan shape and even fell over upon each other. The once flat STRATA of the sedimentary rocks were twisted, folded, broken and pushed one above the other so that they sloped, pointed upwards and even lay upside down. Huge mountains towered

The Alps—a range of folded mountains.
(Photo: Aerofilms.)

into the air—much higher than the Alps or even the Himalayas of to-day, and the original 700 mile band of rocks was compressed into a mountain range 90 miles wide from north to south. The other YOUNG FOLD mountains of the world were formed in the same way, though the GEOSYNCLINE in which the rocks of the Himalayas were laid must have been even greater than that of the ancient Mediterranean Sea. But sea beds they were which provided the mountain rocks, for thousands of feet above the present sea level have been found the FOSSILS of long dead sea creatures which once lived their simple lives below the waves.

So much can be learned by examining the rocks but nothing can tell us with certainty what it was that caused the folding. The most ancient mountains of all, which were formed before there was life or even water upon the Earth, were probably caused by semi-molten granite, lifting in a tide, through the influence of the Sun or Moon, as the sea lifts in tides to-day. But the outer rocks of Earth's crust were not plastic 60,000,000 years ago though the deeper SIMA which cooled more slowly, may have been more easily moved. Some think once more of Earth as an apple and remember how, as the fruit becomes old and dried, it shrinks and causes the skin to wrinkle. These geologists say that the folded mountains are like the wrinkled apple skin and that the wrinkles were caused by the contraction of the cooling rocks of Earth's interior.

Others who do not agree with this idea point out that shrinking alone would not account for the loss of over 600 miles of Earth's crust when the Alps were formed. Instead they think that the THEORY OF CONTINENTAL DRIFT may provide them with an answer. It may be that, as the great rafts of SIAL which were the continents drifted towards or away from each other, they were wrinkled and folded as a tablecloth may wrinkle when pushed over a rough table top.

We may think of drying apples or of untidy tablecloths because they are things which we can see and understand; but we must remember that, because they are so simple and homely, they cannot help us to understand fully the movements of vast masses of rocks. What really happened is a mystery because Earth movements take place so slowly that, even if Man had been on Earth when the Alpine folding took place, he would not have understood what was happening. There were many forces at work in ways which are not properly understood even to-day. Some portions of Earth's crust may have been sinking whilst other parts were rising upon currents of heat from the centre of the Earth. Whilst the crust was being pushed together in one place it was probably being stretched and even broken in another. Earth was in upheaval, but it was not in one violent and sudden earthquake, but in a series of movements lasting for perhaps a million years. Earth may be undergoing a period of mountain building even to-day, for there is no doubt that movements are taking place in Indonesia, Japan and the West Indies. The pillars of a Greek temple by the sea near Naples now stand above the water, but they have in them holes bored by creatures which only live in the sea. Measurements show that 2,000 years ago the temple was 21 feet below its present level, and before that it was 26 feet above it. But Man's buildings and records take us back only a few thousand years. For us to see clearly what is happening to the Earth's crust we should need measurements and marks going back for at least a million years.

A little while ago we thought of a tablecloth which wrinkled when pushed. Now we will have to remember that rocks do not bend easily as cloth does and that, when something can no longer bend, it breaks. Sometimes the great strains which Earth's crust suffered caused the rocks to crack along a line which we call a FAULT. Then the rocks were able to ride one over another and layer piled upon layer, rather as cards will pile if a line of them is pushed against something solid. In some parts of the world: in Africa, Palestine and Germany two FAULTS have appeared parallel with each other in the rocks. This double breaking gave the land the appearance of being in three chunks. Perhaps the two outer chunks were bent down and away from the faults so that the central chunk was allowed to fall between them. Or perhaps as the crust was being squeezed together the two outer chunks rode towards each other, pushed themselves above the central chunk and pressed it down below them. In one of these ways were formed RIFT VALLEYS such as the valley of the Dead Sea, where the floor has dropped to 2,600 feet below sea level, the great Rift Valley of Kenya and part of the valley of the River Rhine.

We can see these rift valleys to-day but we should not expect to find them bordered by sharp edged and overhanging cliffs, for the weather has done its work and has stripped off the overhanging rocks and tumbled them into the valley bottoms where they now form rugged sloping sides.

Faulting and tilting of the rocks brought into being another type of mountain—the BLOCK MOUNTAIN. On one side of the fault the rock layers rose little by little until they stood several thousands of feet above their former companions. By such a fault 400 miles long was formed the Sierra Nevada of California with its steep western ESCARPMENT, rising to a height of two miles, and its more gentle eastern slopes. Now of course the slopes are so worn and rugged that it would not be possible to tell at first sight that it is a block mountain, but geologists study the STRATA of the mountain, find that they are tilted and that they appear in the same order as the STRATA forming the floor of the lowland at the foot of the ESCARPMENT, and from these clues build up a picture in the mind of great tearing and straining which the Earth's crust must have suffered millions of years ago.

Not all the people of Pompeii were able to escape when Vesuvius erupted in A.D. 79 and buried the city beneath 20 feet of ashes and cinders.

Through weak places in Earth's crust, along FAULT lines or where the SIAL layer is thin as it appears to be around the rim of the Pacific, the molten rocks of the under world are able to force their way through to the surface. So a third type of mountain may be formed—the volcano. Scattered over the world there are thousands of volcanoes, about 485 of them which have been active within the history of Man. The rest are quiet, cold and dead and may have been worn away until only the hard IGNEOUS plugs which once blocked their gaping mouths remain; tall and lonely in the middle of the plain as they are at Le Puy-en-Velay in France, or at the Devil's Tower, Wyoming, U.S.A.

We realize what an erupting volcano can do when we look at the remains of the Roman town of Pompeii, which has lain covered by volcanic ash from Mount Vesuvius since A.D. 79. Fortunately for us such eruptions are rare, but even more rare is the sight of a new volcano being born, for this has happened only seven times since Man began to notice and write down such events.

In a cornfield near the little village of Paricutin, Mexico, there used to be a small pit from which came strange rumbling noises and which seemed to warm the air around it. Although stones and rubbish had often been tipped into the hole it never filled up and the local peasants, though warning their children to keep away from it, had become used to its presence.

On February 20th, 1943, at 4.30 p.m., the ground cracked along a line passing through the hole, and dust and ashes began to pour from it. Within a few hours piles of hot dust a foot high had built up round the edge, and by next morning, a cone about four times the height of a man had appeared around the hole which was roaring and throwing out red hot rocks. By midday it was 90 feet high. All the time the pile of cinders and ash grew so that within a few days it was over 400 feet high and it continued growing for three years until it reached 1,500 feet. After four months the new volcano began to pour forth lava which flowed all over the fields and woods to destroy Paricutin and another village. The volcano, named Paricutin after the lost village, is now quiet and is growing no more, but Earth has a new mountain and maps of Mexico have had to be redrawn to show it.

A volcanic mountain can usually be recognized by its even, conical shape. One of the best known and most beautiful is Japan's sacred Fuji Yama which sprang from the ground during a dreadful earthquake one night in 286 B.C. and which last erupted in 1707.

Not always, however, does a volcano cause a cone-shaped mountain to rise. The biggest bang in history happened when, in 1883, the volcanic island of Krakatoa in the East Indies blew its 1,400 foot high top right off, throwing rocks upwards for 34 miles, and left a ring of tiny islands. The noise was heard 3,000 miles away some four hours after the explosion; and the only man who saw it happen was knocked unconscious although he was on an island 30 miles away. The great (and wrongly named) TIDAL WAVES which came afterwards travelled all round the world and drowned 100,000 people in Java and Sumatra. The dust from the explosion was blown round the world at a height of twenty miles.

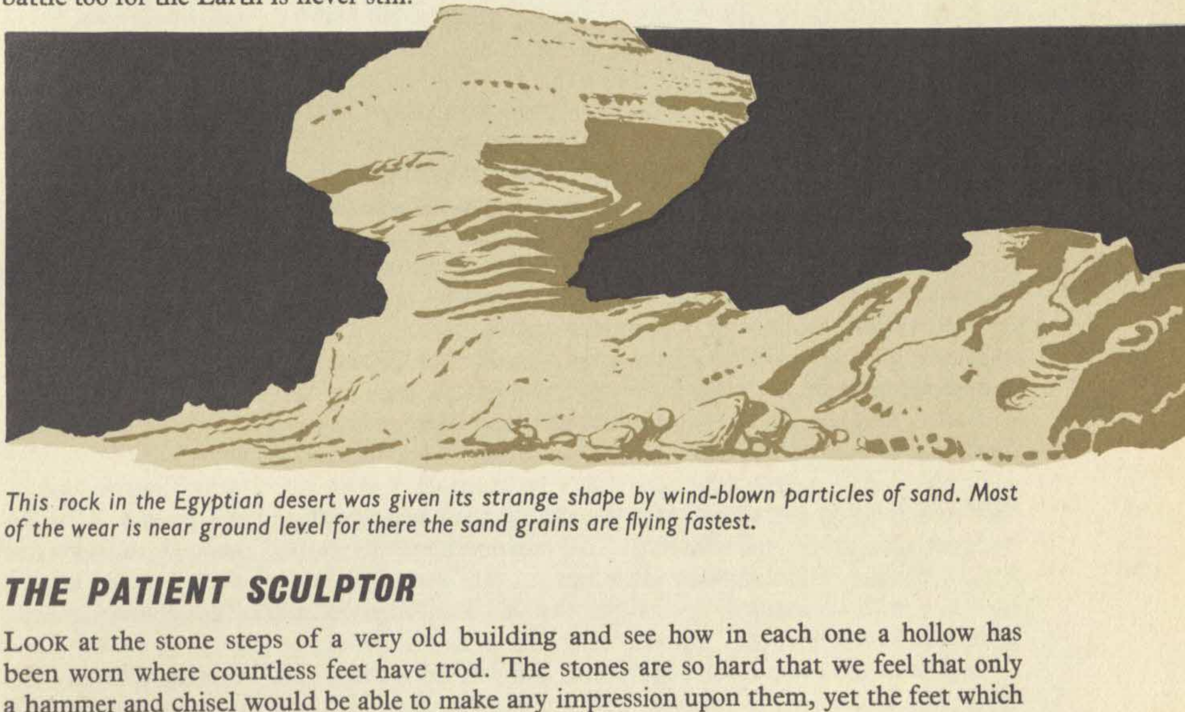
This church at Le Puy is built on a volcanic rock 280 feet high. (Photo: Aerofilms.)

It is the dust which is normally in the air which causes the colour of the sunset, and for two years after the volcanic explosion the dust of Krakatoa gave the world some of the most glorious sunsets ever seen.

Sometimes earthquakes reshape the land without any volcanic cone forming. Islands in the Pacific appear and disappear as the sea bed shifts. In 1831 an island appeared in the Mediterranean Sea. It was named Graham Island but before the nations had finished arguing about who owned it, it sank again beneath the sea! As a result of the Agadir earthquakes in 1960 mountains rose from the sea bed to very near the surface—so becoming a danger to shipping in the harbour.

* * * * *

The three types of mountain—fold, block and volcanic—were formed by great forces within the Earth itself as if a giant of enormous strength had pushed, cracked and melted the rocks to give Earth a new surface. Sometimes sudden, and often terrifying, must have been the creation of mountains, but the rest of their story is one of slow destruction; for leisurely and patiently the weather wears them away. It is an old battle between the giant of the Earth itself and the weather, child of the ATMOSPHERE,—an unending battle too for the Earth is never still.



This rock in the Egyptian desert was given its strange shape by wind-blown particles of sand. Most of the wear is near ground level for there the sand grains are flying fastest.

THE PATIENT SCULPTOR

Look at the stone steps of a very old building and see how in each one a hollow has been worn where countless feet have trod. The stones are so hard that we feel that only a hammer and chisel would be able to make any impression upon them, yet the feet which climbed those steps were wearing nothing harder or stronger than leather. It is the passing of time which has made this happen. A few hundred years are enough for the stone steps to have been worn away, but Nature has had millions of years in which to wear away the rocks and change the face of the land.

If our planet had neither ATMOSPHERE or water there would be no soil nor any rocks other than IGNEOUS. Volcanoes and mountains of folded granite would reach upwards for miles and would remain thus until another great movement of Earth's interior collapsed them.

Such a barren world is the Moon. Its surface has never changed except when struck by falling meteors which have marked its face with deep craters.

When we look at a rusty can we are seeing a way in which the atmosphere destroys metal. Chemical changes of the same sort are going on all the while in the ground as the gases of the atmosphere combine with water to eat into the rocks. Iron bearing rocks receive oxygen from the atmosphere and become soft and brown as does the rusty can. The chemical change is the same, for *iron oxide* is being formed. Some of the carbon dioxide which the atmosphere contains dissolves in rain water to form a very weak acid which eats into limestone rocks and has hollowed out the caves in Derbyshire and Somerset where 'potholers' explore and risk their lives following the courses of underground rivers.

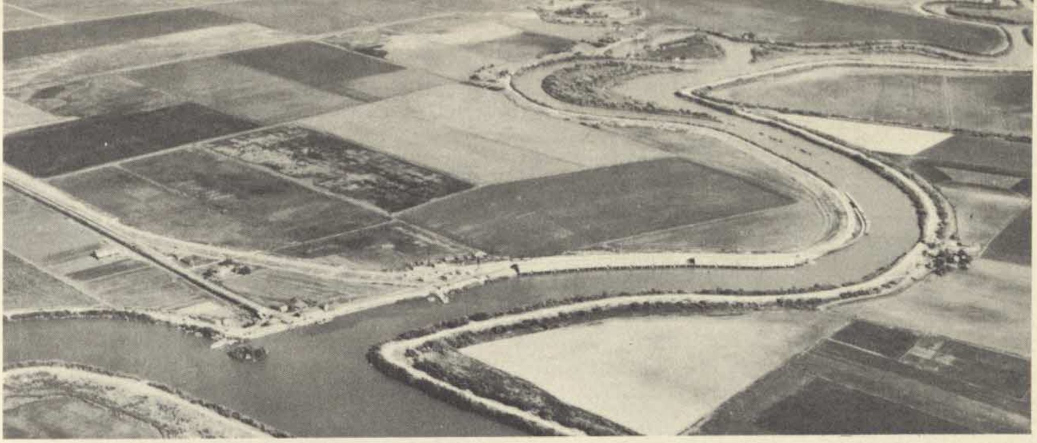
Water seeps into the cracks in rocks and lies there. Then comes a frost and the water freezes, expanding as it does so to crack the rock as easily as ice splits the water pipes in our homes in winter.

The rocks of the desert are not likely to be soaked by rain yet the weather cracks them. Just as boiling water will crack a cold glass into which it is poured so will the heat of the day, followed by the cold of the night, shatter the desert rocks. Once the rain or heat or frost has begun its destructive work it continues until smaller and smaller fragments are formed. Then these stones or pebbles fall and rub against each other or are carried by the wind and the wash of the rain to rub and break again until they become sand, dust or mud.

Were it not for the weather breaking up the rocks there would be no soil and no plants would grow, but the weather often causes soil to disappear, destroying the fertile land. Grass, trees and other plants bind the soil together so that wind and water carry it away less easily. If Man, either in his ignorance or in his greed, ill-treats the soil by growing, year after year, the same crop without spreading manure, the HUMUS is destroyed and the soil becomes lifeless. This happened during the 1930's on the plains of U.S.A. Thousands of acres of soil were exhausted and left bare of their original protective vegetation. During several dry summers the wind swept up the fine fertile top soil and carried it eastwards in great clouds, over Chicago where the sun was blacked out at midday, and on until it fell on the decks of ships in the Atlantic Ocean. Much of Kansas and the Dakotas was left so dry and lifeless that the area was called the *dust bowl.*

In North Africa desert sand may now be seen where once there were trees and grass. Some of the blame may be laid on herds of goats which cropped the grass and bushes so short that they died. Nothing then remained to keep at bay the wind-blown sand from the Sahara. Now modern soil scientists, who seek more land to feed a hungry world, are faced with the problem of halting this SOIL EROSION and of correcting the folly of hundreds of years.

Look at a sandy slope after a rain storm and you will see how running water cuts channels for itself and carries with it sand from the high slopes which it drops when the flat floor is reached again. Rivers are doing this all the while—floating light particles bodily and rolling boulders along their beds—stripping the land to cast it into the sea. The Mississippi river drains an area as large as half Europe and robs from it over a million tons of mud per day. Much of this mud has been dropped at the river's mouth and has extended the land for about 2,000 miles during the last 120,000 years. Thus the river 'robs Peter to pay Paul'—Paul sometimes being the floor of a flat valley, sometimes a DELTA and



Over a flat valley floor the river wanders, sometimes changing its course and leaving behind it mud which has formed the fertile soil of the fields. (Photo: Aerofilms.)

sometimes the muddy sea bed.

All the silt, stones and boulders which a river carries along with it help to wear away its banks even more. Stones rub and jostle on the river bed and carve for themselves holes which in time join up to make a deeper channel. A river valley is formed which grows ever deeper and wider until sea level is reached and the once swift stream flows slowly.

River valleys can be young or old and the difference is easy to see. A young valley is V-shaped, a cleft in the rocks through which the stream rushes over its bounder strewn bed. As time passes the sides of the valley are lowered by smaller streams and the wash of rain, the boulders are worn to gravel and the slope of the stream itself is less steep so that it makes its way less hurriedly towards the sea. As the floor of the valley becomes flat, MEANDERS form in the slow river and, during flood time, a layer of ALLUVIUM is dropped in the valley where it makes good fertile land.

Sometimes a river may flow through a region where there is no rainfall. When this happens a deep valley with steep sides is cut. For then there are no small streams to wear down the valley sides as they seek to join the main stream. The Colorado River has had to cross 300 miles of the Arizona desert, and throughout a million years has cut for itself the GRAND CANYON—in places a mile in depth.

On its journey towards the sea a river may pass over hard rock, such as *limestone* on to a softer *shale*. The soft rock wears down more quickly and in it the river deepens its bed until it finds itself falling over a step of hard rock. This has happened to the Niagara river between the American lakes Erie and Ontario where stands the mighty Niagara Falls. At the foot of a waterfall the water swirls with such force that the rock step is undercut and in time collapses. In this way the waters of Niagara, falling into the pool below at 50 miles per hour, are cutting the falls back at a rate of three or four feet per year and, during the last 7,000 or 8,000 years have left behind them a GORGE seven miles long.

Even more formidable than a river of water as a sculptor of the rocks is a river of ice, for that is how we might describe a GLACIER. Where snow remains throughout the year and is able to pile up to a depth of 100 feet or more high in the mountains, or to several thousand feet in Greenland and the Antarctic, it is pressed together to form ice and begins to flow or creep, Remember that, under the weight of mountains, even rock can flow and that what seems to us to be hard and brittle behaves very differently when under pressure. The flow of an ice river can hardly be seen by those who watch

The Grand Canyon of the Colorado River.

it for it may move only a couple of feet per day, though at one place in Greenland the ice seems to be racing along at 100 feet per day. When a glacier reaches the lower slopes of a mountain it usually begins to melt and, from underneath it, appears a mountain stream. The glaciers of Greenland and Antarctica, however, usually reach the sea before they melt and their feet hang out over the sea until great blocks break off to form icebergs.

In the North Atlantic bergs are a great danger to shipping from March to August. Although most of them will melt when they meet the warm waters of the Gulf Stream Drift, a lump of ice as big as a sitting room was once seen floating between Bermuda and the coast of Africa. The Southern Ocean is the home of huge icebergs which may be several miles long, (in 1956 an iceberg 208 miles long and 60 miles broad was seen) but fortunately they are able to drift for thousands of miles without meeting any shipping.

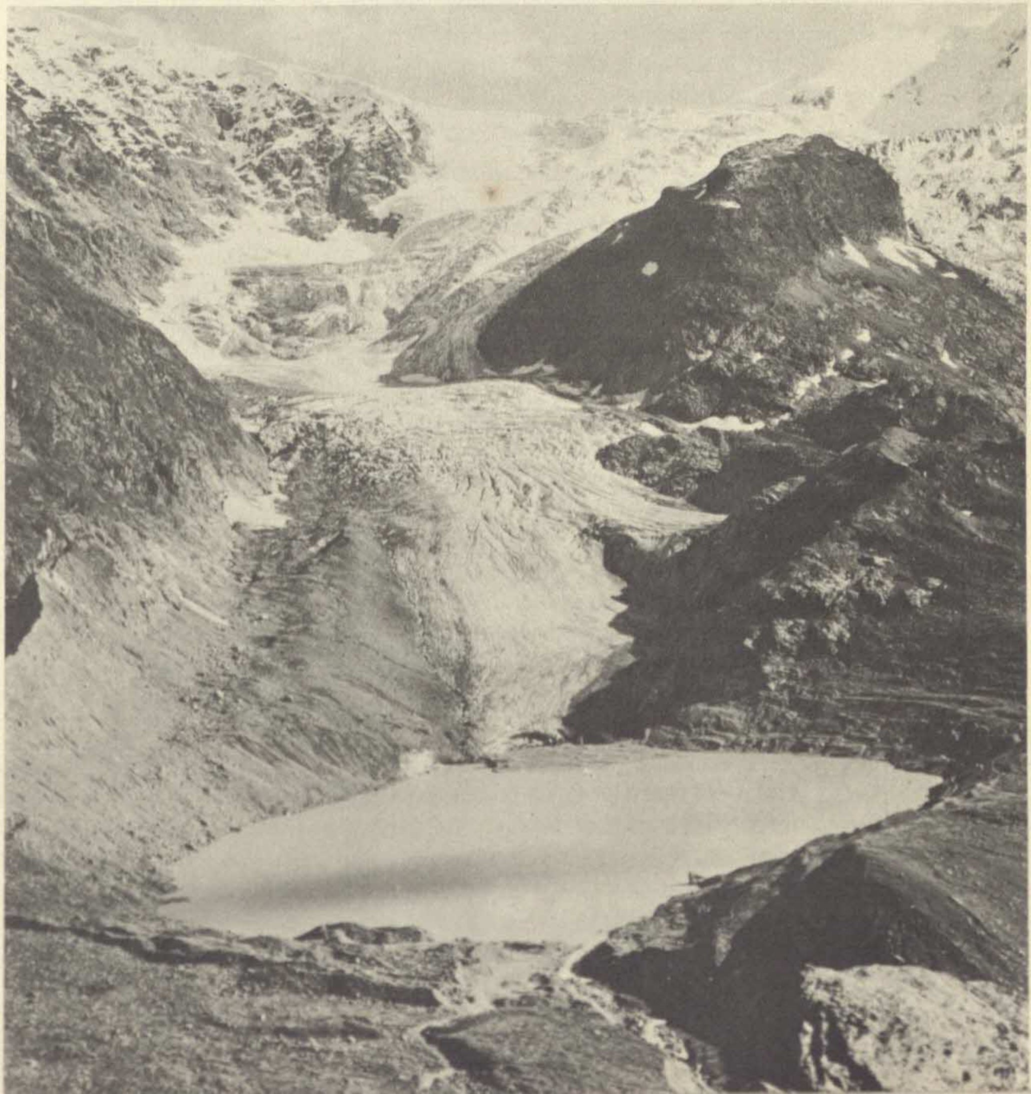
The damage which floating ice may do to ships is sudden, dramatic and frightening, but ice has done greater damage to the land though it has taken its time about it. A glacier pushes rocks and loose soil in front of it and drags along with it great boulders which scrape, gouge and pluck at the sides of the river valley through which it flows until it has given that valley the shape of a U instead of its former V. High in the mountains glaciers have carved out hollows called *corries* or *cirques* which sometimes have filled with water to become mountain lakes. When several glaciers on different sides of a mountain have carved out these hollows they have left tall, sharp pinnacles with CONCAVE slopes and sharp ridges such as may be seen in the Alps or Himalayas.

If the climate grows warmer and a glacier retreats it leaves behind it the rocks which once it pushed in front or dragged with it. These may be seen as long ridges called *moraines* or small round hills called *drumlins*. Sometimes glaciers have carried large boulders and dropped them in a district where the rocks are of a completely diffent type. Such an *erratic block* may be balanced on another rock in a manner which it would puzzle an engineer to imitate. The foreign block rested where the glacier dropped it, the years passed and the ground around was eroded so that it was left standing clear of the ground—an object of wonder to those who see it.

But the glaciers of to-day, which seem to be growing smaller as the Earth enjoys what is probably a temporary warm spell, are as nothing compared with the glaciers of the last ICE AGE which ended some 12,000 years ago. Within a million years the glaciers grew and shrank again four times, and for several thousand years ice sheets covered a quarter of Earth's land surface. America was covered as far south as Kentucky, and Britain as far south as Bristol. Beneath the weight of a layer of ice over a mile thick the mountains of Scotland were ground to a smooth shape, the valleys gouged and the long, deep lake beds scooped out. The layer of *boulder clay* which makes the good farmlands of East Anglia was dumped there by the ice sheet. In America *moraines* left behind when the ice retreated have dammed rivers to form some of the smaller lakes such as Lake Wisconsin; the subsoil of the prairies was brought from the north-east and left behind, so now the farmer of the corn belt of the U.S.A. is growing his crops on soil which really belongs to Canada.

But that is what always happens when EROSION takes place—the soil of central U.S.A. came from Canada and now it is being washed into the Gulf of Mexico, the rock collected by the Greenland ice cap floats away on an iceberg and is dropped into the sea so helping to build up the GRAND BANKS of Newfoundland, desert sands are blown from one place to another and form dunes whose shape is always changing, and all the while the sea is gnawing at the shores—but do not worry; the land will not disappear before our eyes for new land is constantly rising from the sea as the rafts which are the continents float higher upon their bed of SIMA.

The glacier has scooped out the hollow which is now filled with water melted from the glacier's foot.
(Photo: Paul Popper Ltd.)



The flat lands of Holland suffered badly from the North Sea floods of February 1953. (Photo: Aerofilms.)

THE WORK OF THE SEA

THE last night of the month of January 1953 was one of terror for many of the people living on the east coast of England and the west coast of Holland. To them it must have seemed that night as though the sea was not merely gnawing but swallowing their land. During the hours of darkness the soft face of a six foot high cliff in Suffolk was cut back 90 feet, and even where the cliff was 40 feet high a strip of land 40 feet wide was washed away.

But fortunately the sea is not often so sudden nor so destructive, for that winter's night was exceptional. The North Sea, whose waters wash the coasts of Lincolnshire, Norfolk and Suffolk, sometimes suffers from *surges* which raise the water several feet above its normal level. Through the wide northern mouth of the North Sea, between the coasts of Scotland and Norway, pours the tide. When the tide is assisted by northerly winds the waters pile up in the North Sea, for the twenty mile gap of the English Channel between Dover and Calais is not wide enough to allow the mounting waters to escape quickly.

We imagine that the sea is level, but it is not always so, for the same reasons that a mattress is not level when we lie upon it. Air has weight, and the weight or *pressure* of the ATMOSPHERE varies according to whether the air is warm or cold, wet or dry. From the 30th January to the 1st February 1953 the pressure was low over the North Sea and the level of water rose as a mattress rises when we get out of bed.

It looks at first as though everything was in league against the low lying lands of England and Holland—yet things could have been worse! Had the *surge* occurred a fortnight later it would have happened at the same time as the highest SPRING TIDE of the year and the water would have been another two or three feet higher. Even so, at one point in Lincolnshire, the water reached 7½ feet above the level foretold by the tide tables.

To people on such coasts the sea is a challenge and often an enemy. They have to protect themselves against it and, in order to be safe, they prepare to resist the worst that could happen—a rise in the water of perhaps ten or twelve feet above the level of the highest tide. In some places concrete walls have been built and these, standing square and massive—thick enough for people to promenade in comfort along their tops, look as though they could defy the mightiest seas. Yet such formidable works seem to make a challenge which the sea feels bound to accept, for it is not the stout unyielding concrete which best keeps the sea at bay.

When storm waves break against the walls the water in them swirls downwards and under to scour away the beach and deepen the water in front of the wall. The shallow, gently sloping sea bed disappears and the waves are allowed to roll in from the open sea, free and fast without any shallow bottom pulling at them and trying to slow them down. More and more is scooped away and the sea begins to undermine the wall until eventually it collapses under its own unsupported weight.

Great storm waves can also break with such force against a wall that they hurl thousands of gallons behind it. This water collects to flood the land and also helps to undermine the wall from the rear.

Just as the frail reed bends before the gale and afterwards recovers, so it is that dunes of soft wind-blown sand are able to withstand the strength of the sea because they allow the waves to waste their energy as they plunge into the sandy cushion. It is easy to realize, when we look at a pile of builders' sand after a rain storm, that sand by itself is useless as a defence against water. The dunes, however, which in places protect our coastline are laced together by a network of tough plants. *Marram grass* thrives on sand, it helps to trap and keep sand the wind blows on to the dunes and its underground stems go deep, binding it together so that water may pour through it yet not wash it away.

A high, wide beach will also prevent the land from being ERODED by the sea. As it is the sea itself which builds beaches by piling up sand and shingle which have been stolen from somewhere else, GROYNES are built to halt the moving beach material and allow it to collect where it is most needed.

A striking example of coastal erosion.
(Photo: Crown Copyright Geological Survey reproduced by permission of the Controller of H.M.S.O.)

Man sometimes wages a slow, desperate war against the sea—and wins. Dutch engineers have built dams across parts of the Zuyder Zee, pumped out the water and made POLDERS which soon became fertile farmland. But those who seek to rob the sea must be forever on their guard or they will lose what they have gained. Just off the coast of Essex is a small island which once possessed a brick-works, houses, shops, a school, a large prosperous farm and one tree! At the time of the SPRING TIDES the sea rose higher than the land on which the people lived, but they were protected by five miles of sea wall which ran all round their island. When the brick-works closed most of the people left but the farmer remained. In 1925, however, there came a new farmer who did not understand how important was the wall which surrounded him. He paid for his carelessness, for one night a SPRING TIDE breached the wall, flooded the island, drowned his cattle and the wild rabbits and carried his haystacks out to sea. Now no one lives on the island except for the sea birds which perch on the blackened stump of the dead tree or rest among the ruins of the farmhouse. And every Spring Tide a little more of the island is washed away.

Although it is flat coasts of soft rock which suffer most from the sea, the most exciting examples of the sea's carvings may be seen in rocky coasts such as those of Dorset, Devon and Cornwall. To the human eye these coasts have scarcely changed in a thousand years but the sea has had sufficient time to carve strange shapes out of rocks which we would be able to cut only with a chisel.

Where there have been hard and soft rocks close to each other the softer ones have worn away first, leaving caves and arches through which the waves swirl. Sometimes the caves have grown so large and their roofs so thin that the arches have collapsed and left tall *stacks* or pillars of rock standing alone some distance from the shore. In some places there is a band of soft rock just behind the hard rocks of the cliff. If the sea can once break through the hard protective rocks it is able to scoop out more quickly the soft inland rocks. This has happened at the strange and lovely Lulworth Cove in Dorset, where a perfectly circular harbour is reached through a narrow gate which the sea cut in the limestone cliffs.

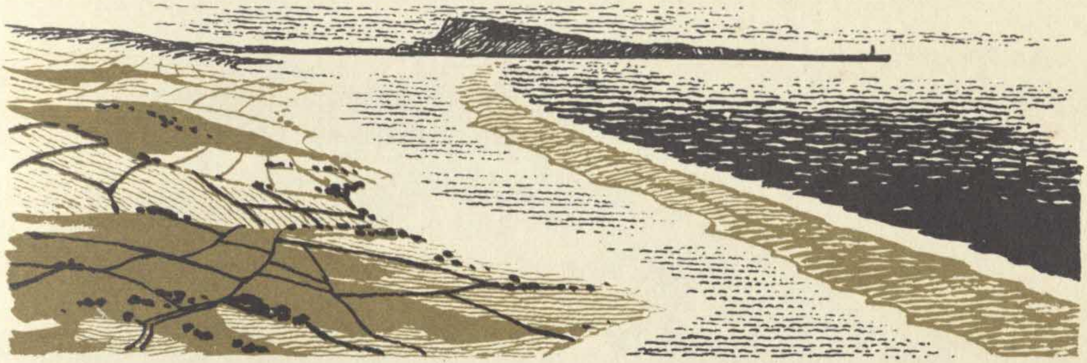
The great storm waves have a terrible power of destruction. A door 195 feet above sea level has been broken down by spray from waves raging against the Shetland Islands, and pebbles from the beach have been swept 300 feet into the air to break the windows of a lighthouse. Nothing would seem more solid to us than a block of concrete, but at Wick in Scotland a concrete breakwater weighing 1,300 tons was moved out of its position during a storm. Yet the hammer-like blows which waves deliver to the cliffs are not the chief cause of destruction. Air which is trapped in the cracks of the rocks, is compressed as the waves slap against them; and the compressed air, unable to escape, prises away slabs of rock from behind. Water, also lying in the cracks, is forced into a space too small to contain it. With the force of a hydraulic ram it splits off more slabs which tumble and break into the hungry sea below. Here they become ammunition for the sea to hurl at the base of the cliff, hacking out hollows in the rock so that the cliff begins to overhang its base like the eaves of some old house. There comes a time when the overhang becomes too great and, with nothing to support the cliff face, it falls and many tons of rock fall into the sea to join with what went before and begin the wearing away process all over again.

This view of the Dorset coast shows how the sea has scooped out the more distant Lulworth Cove and has begun to repeat the process by cutting in the hard cliffs an opening known as Durdle Door.

Some cliffs can be attacked by the sea even in the calmest weather for the salt water can wear away by chemical means rocks such as limestone.

Those who experience the power of the waves and see, perched on the edge of a cliff houses which once stood some distance inland have good reason to believe that the land is bound to disappear eventually. The people of Dunwich in Suffolk live in what is now only a small and disappearing village. No doubt some of them can remember when their church disappeared in 1920 but all have learned of what Dunwich used to be—a busy and important port and the home of a bishop. Now the waves roll over the streets and the palace, and before long Dunwich will be only a name on old maps.

But the sea does not only destroy; it also makes land where there was none before. Between 1875 and 1910 4,600 acres of land were lost from the coasts of England and Wales but eight times as much was added! Perhaps we do not appreciate this profit because much of the land which is lost is capable of producing food or has houses built upon it, whereas what the sea creates cannot for many years be put to any good use. For the work



The shingle of the Chesil Beach was piled up by the waves and tide to form a bar which runs parallel with the Dorset coast.

of the sea is seen in salt marshes, sand banks and shingle spits.

Deep short waves destroy a beach, but long shallow waves cast up material to make a beach higher. Sometimes the waves move along a shore rather than directly towards it. They cause a *longshore drift* in which sand, shingle and even pebbles are slid and carried along a coast. One might expect the drifting material to continue in this way until the coasts at one end of a sea had been stripped and the furthest end of the sea filled up. This would happen were it not for headlands, river mouths and currents of water which flow in the opposite direction and interrupt the *longshore drift*.

In the English Channel sand and shingle are moving continually from west to east. Sand from Devon is found on Kentish beaches and some of the shingle of the famous Chesil Beach of Dorset has come from the cliffs of the West Country. The Chesil Beach stretches along the coast of Dorset for 18 miles, and for 12 of those miles the shingle is piled up at some distance from the shore so that there is a lagoon called the Fleet between it and the land. The last two miles of the beach continue beyond the land to reach the isle of Portland and so form that island's only natural link with the mainland.

Along the coast of Suffolk stretches a bank of shingle which for eleven miles prevents a river from reaching the sea. Although at times it is only a few yards from the sea, the river has to flow parallel with the shore until it reaches the tip of this bank known as Orford Ness.

At the mouth of Southampton Water, where many currents meet, the sand and mud carried by the sea has been dropped to form the long, strangely curved Hurst Castle Spit.

In sheltered bays and river mouths silt and mud is dropped to form banks upon which salt-loving plants will grow. So a salt marsh will form, but so long as the sea covers the marsh at high tide ordinary soil will not form and field plants will not grow. But if man takes a hand and reclaims the marsh by building a bank around it he can drain off the salty water, and very quickly grasses, buttercups and daisies will start to grow instead, in soil that has been washed clean by rain. Around the Wash in Lincolnshire where there are many salt marshes a considerable amount of land has been reclaimed, has had the farmer's plough over it and has borne several good crops.

So, in places only a few miles away from each other on England's East Coast, the varied work of the sea may be seen—the EROSION of cliffs and the breaking of dykes by storm waves and *surges*, and the gentle laying down of silt which in time may become as valuable as the land which was lost.

EARTH'S OUTER WRAPPING

We live at the bottom of a sea—a sea of gases which we call the ATMOSPHERE. If we were asked what was most necessary for life most of us would mention food and water, yet if our atmosphere were taken from us we would die more surely and swiftly than a fish left stranded by the tide. To some of us air is merely something which we put in our bicycle tyres; but without it none of us could live for more than a few minutes, whereas it is possible to live for a few days without water and for a few weeks without food.

When a person or animal is deprived of air he dies because one-fifth of the atmosphere is *oxygen*. This is the gas which causes fires to burn, petrol engines to run and our bodies to work. Oxygen is a gas which combines easily with other substances. When it meets carbon, either in our bodies or in fuel such as coal or petrol, it forms the gas carbon dioxide and releases heat and energy which keep us and the machines of the world going. With the hydrogen which petrol contains, oxygen joins to form water. That is why we sometimes can see drops of water forming at the end of a motor car's exhaust pipe.

When oxygen joins with carbon and hydrogen to provide energy it is serving man, but when it joins with other substances it sometimes acts against man's interests. The oxygen which is in water joins with iron, for instance, to form iron oxide which we know better as rust. For this reason we have to protect tools with grease, and keep bridges and girders covered with a coat of paint.

We use water to dilute or make weaker the fruit juices which we drink. If we did not do so many of them would taste unpleasantly strong. In the same way the oxygen in the air is diluted by the gas *nitrogen*. Pure oxygen can be manufactured or taken from the air by industrial methods and is sometimes used by hospitals to revive unconscious patients. The pure gas helps the tired body to work better and releases heat and energy. When pure oxygen is pumped through a blast furnace it does its job of smelting iron much more efficiently. If our atmosphere contained a larger amount of oxygen flames would burn more brightly, engines would run faster, human bodies would work with greater energy (and wear themselves out sooner) and rust would form more quickly. Life would be shorter, faster but not necessarily more enjoyable.

For one thing there might not be enough to eat as more oxygen would mean there would be less nitrogen, and nitrogen is responsible for much of our food. The proportions of gases in the ATMOSPHERE are roughly 21% oxygen and 78% nitrogen (added together these make 99%—what the other 1% consists of we will come to later). There is nearly four times as much nitrogen as oxygen in the air so the stuff we breathe may be compared to a very weak drink. But nitrogen does more than simply dilute the atmosphere. It enters the soil of our fields, the grass and clover of our pastures, the peas and beans in our gardens and the corn from which we make our bread. In the bodies of clover-eating cattle and bean-and-beef-eating humans the nitrogen forms PROTEINS—the substances which form half the dry weight of our bodies in muscle, skin, blood and bone. Whenever we eat cheese, eggs, butter, meat or fish we are eating foods which contain large amounts of protein. From the plant food which the cattle and poultry ate they obtained their protein and the plants formed it from NITRATES in the soil.

Unlike oxygen nitrogen is a lazy gas which does not join easily with other substances.

The lightning flash, the farmer's artificial manure and the bean plant all help to put into the soil the NITRATES upon which our supplies of milk, beef and eggs depend.

We cannot make protein for ourselves for our bodies cannot take nitrogen from the air when we breathe. Neither can plants absorb nitrogen through their leaves. Above every square mile of the Earth's surface the atmosphere holds 20 million tons of nitrogen which is waiting to be used. It is the task of certain BACTERIA which live in the top few inches of the soil, to capture this nitrogen and turn it into nitrates which dissolve when it rains and which are absorbed by the plants. Certain plants such as peas, beans, lupins and clover provide homes in their roots for other bacteria which, like their cousins in the soil, are able to capture nitrogen and turn it into nitrates. These plants are good for the soil and wise farmers will grow a crop of beans or clover between crops of corn so that the soil may regain the nitrates which the previous crop took out of it. Sometimes when the soil is very poor, a crop of beans may be grown chiefly so that it may be ploughed in again to nourish the soil. When, on the other hand, man has been greedy and has tried to raise crop after crop of corn on the same soil without putting back the goodness he has taken, Nature punishes him by causing the soil to become useless; then plant life disappears and the HUMUS is washed or blown away so that only dust or naked rock is left.

The work of the soil bacteria can be helped by spreading the fields with manufactured nitrates and with manure from animals which have fed off the grass and have allowed nitrates to travel in a circle through their bodies to the fields again.

Few of us can see much good in a thunderstorm, yet every time the lightning flashes a chemical reaction takes place which helps to feed us. The electric charge of a flash of lightning converts the nitrogen and oxygen in the air to nitrates

This farm has been abandoned because nothing will grow on the barren wind-swept land which has been robbed of its goodness by thoughtless, greedy farming.

which dissolve in the rain, wash into the soil and enter the roots of plants.

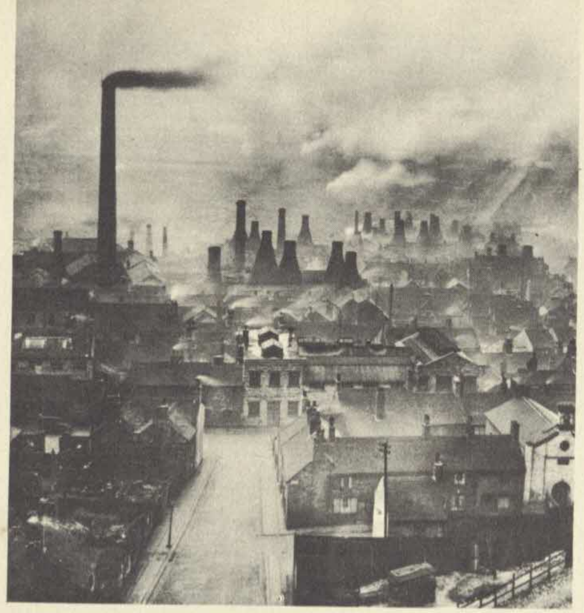
After nitrogen and oxygen the next most common atmospheric gas is *argon* which takes up nearly one part in a hundred. It is an even lazier gas than nitrogen and does not seem to join with anything or have any part to play. It has a use, however, for it can be separated from the air and is often used to fill electric light bulbs.

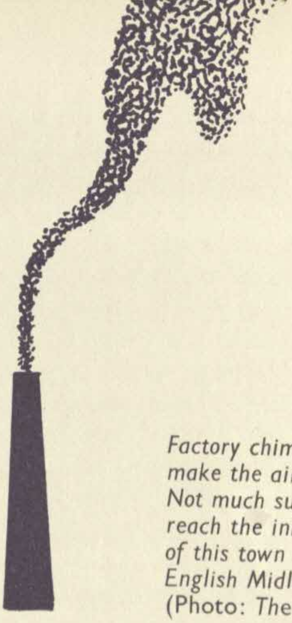
The next most common gas is one of which we all have heard—*carbon dioxide*. Since we are forever making more of this gas as we breathe out, and as fires and engines are making it whilst they burn or run, one might expect that there would be far more of it in the air. When a crowd of people sit in an unventilated room for a long while the air becomes stale and they begin to feel tired and lazy. The stale air is air which has had most of its oxygen changed into carbon dioxide. Certainly in that room the proportions of gases have been changed but once the windows are opened the extra carbon dioxide will enter the atmosphere and be lost in its vastness. But all the while that animals are making carbon dioxide plants are making use of it. Some of it dissolves in the rain and soaks into the soil or flows into the sea (which has dissolved in its waters 50 times as much as hangs in the atmosphere). As the air filters through the leaves of plants carbon dioxide is absorbed and turned into carbon and oxygen. The carbon builds the tissues of the plant and with the help of sunlight makes sugars (for it is not only the sugar cane which contains sugar—there is sugar in the flowers of the garden as well the honey-making bee knows). The oxygen which the plants make is released into the atmosphere to find another job.

So it is that the amount of carbon dioxide in the air remains pretty steady at 3 parts in 10,000. But it may not always have been so. Man may have changed the atmosphere of his world and incidentally may be changing the climate too. For millions of years vast stores of carbon have lain in the earth as coal and oil. Long ago these fuels were formed by trees and small sea creatures which lived, died, decayed and were buried under the rocks. During the last hundred years or so man has been digging or drilling for the coal and oil and burning them at great speed in his fires, trains, cars and planes. Carbon which took millions of years to form has been turned into carbon dioxide in a very short while.

Just as the glass in a greenhouse traps the heat of the Sun and keeps it to warm the delicate plants so does the carbon dioxide in the atmosphere blanket the Earth. The Sun's rays are absorbed by Earth but the heat which the Earth in its turn radiates will not so easily penetrate an atmosphere heavy with carbon dioxide. Earth's climate does seem to be growing warmer for GLACIERS are growing shorter and polar ice caps are dwindling. Some think that this may be due to man's factory chimneys and engines pouring out carbon dioxide, but earth has grown warmer and cooled again many times without man's aid.

Look at a boiling kettle and you will see that a cloud of steam forms, not at the end of the spout but about half an inch away. There appears to be nothing in the first half inch but do not therefore be tempted to pass your fingers between the spout and the cloud or you will be badly scalded. There is water there in the form of vapour or gas and as a gas it is invisible. Air which is hot or warm will hold a great deal of invisible water vapour but when the air cools the vapour turns back into tiny drops of water which hang in the atmosphere. The air a few inches in front of a kettle is cool, and no longer can it keep hidden a great quantity of vapour. We see instead a cloud of tiny water drops which float about the room until they evaporate again or settle on the cold face of a mirror or window.





Factory chimneys make the air filthy. Not much sunlight can reach the inhabitants of this town in the English Midlands. (Photo: *The Times*.)

There is *water vapour* in the atmosphere everywhere, but not always the same amount. On a hot muggy day in summer the air holds far more water than it does on a cold, crisp winter day. We cannot see the water until the air becomes too cold to hold it as vapour. Then clouds form either in the cold upper air or as fog at ground level in the cold damp winter days.

Much of the rain which falls on the land finds its way into the sea which is quite unfit to drink and not very suitable for washing with either. But most of us are assured of a never failing supply of fresh water because our atmosphere is restless and because of the ease with which water evaporates and becomes part of the moving air. Minute particles of pure water are swept off the surface of lakes and seas, off roads drying after a shower and off washing drying in the wind. They stay in the atmosphere until it can no longer hold them and then they fall as rain, snow or hail. The whole story of our weather is the story of hot or cold, and wet or dry layers of air—how they move, how they meet and affect each other. To-day's rain, yesterday's high wind or next week's heat wave are all caused by changes somewhere in the pattern of the atmosphere.

Although by now we have accounted for well over 99% of the atmosphere there still exist many other gases which between them make up one part in 100,000. There is *helium* which, because of its lightness, is used for lifting airships and balloons. *Neon*, another rare gas, glows bright red when an electric current passes through it and is used to fill the lamps which flash in the advertisements and shop signs of our towns by night. *Krypton* and *xenon* are used to fill flash bulbs for high speed photography. *Methane*, a gas which is plentiful in the atmosphere of some planets, is fortunately rare in ours for it is the poisonous gas sometimes known as *marsh gas*.

Also floating in the air at fairly low levels are small amounts of dust, soot, salt particles, pollen and BACTERIA. The amounts vary from place to place and although Man does his best to poison the air he breathes by pouring into it filth from factory chimneys, fortunately the winds carry most of it away from the cities and dilute it until it is safe to breathe. Even so the soot and dirt in city air does millions of pounds worth of damage to buildings, kills plants in parks and gardens, cuts off the sunlight and so damages the health of city dwellers, dirties and spoils the curtains, clothes and washing of the housewives, and provides dust particles upon which water condenses to give us the fogs and 'smogs' which, especially in London, bring delicate people to their beds and traffic to a standstill.

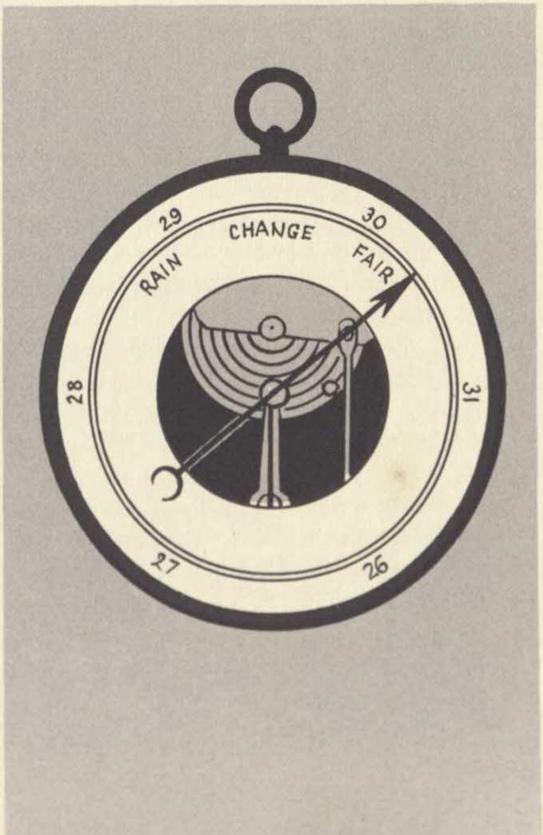
This chapter began by saying that the atmosphere is a sea of gases and that we live at the bottom. Perhaps the flat fish lying on the mud of the ocean floor imagines that there is no end to the water above. We know that the fish is wrong however and that the sea ends suddenly and quite definitely at the surface, and that there the air begins. We are in a more fortunate position than the flat fish for we have been able to explore our sea and we know that, although the atmosphere becomes thinner the higher we go, there is no definite point at which the atmosphere ends and completely empty space begins.

Air has weight and, although we cannot feel it for it surrounds us on every side, we have several hundredweights of atmosphere above us all the while. By the time we have reached the summit of Everest, 29,000 feet above sea level, most of the atmosphere lies below us. At this height the air is so thin that a mountaineer cannot work for long without supplies of oxygen. At a height of 60 miles there remains only a millionth part of the air that there is at sea level so rare do the particles of gas become.

Although there are no sudden changes in the form of the atmosphere it has been found convenient to think of a series of layers. The lowest layer of all we call the TROPOSPHERE. It is in these first few miles that most of our weather is formed for here is most of the dust and water vapour. As we rise through the troposphere the temperature falls to between −67 degrees and −112 degrees.

After the troposphere comes the STRATOSPHERE where the air is thin, dry, pure and cold. Here fly the great airliners with pressurized cabins containing their own private atmospheres. By choosing to fly at great heights the 'Stratocruisers' avoid bad weather and can sometimes speed their flights by riding with the JET STREAMS.

Much of the atmosphere is still unexplored and a great deal more will have to be learned about the higher levels such as the IONOSPHERE and beyond. For although we realize that the atmosphere protects us and gives us life, the future may show us that it affects us in ways undreamed of at present.



The weight of the air, which varies with the weather, causes a metal box which you can see inside this Aneroid Barometer to expand and contract. This movement operates the pointer.

THE LAYER OF LIFE

WHEN one day the first man lands on the Moon it is not likely that he will find much to interest him apart from barren rocks and craters. On the Moon there is no weather so there has been no EROSION of rocks into the patterns which we know on Earth; but what the first lunar explorer will miss most will be all the various forms of life which make Earth so interesting. We talk about the various layers of rocks which make up Earth's crust, about the layer of water and the enveloping layer of the ATMOSPHERE, but we can also talk of a 'layer of life', for living things surround the Earth and are found on the rocks, in the water and in the atmosphere. We realize that no form of life, as we know it, could exist in the great heat of the bright face of Mercury, or in the intense cold of Pluto but it is wonderful how creatures can live under some of the widely different conditions found on Earth.

The sea covers most of Earth's surface, and it is in the sea, with its temperatures less extreme than those on land, that life flourishes most widely. Beneath the ice of the Arctic Ocean are so many DIATOMS and other forms of PLANKTON that the waters are often coloured green. They provide food for fish which in their turn feed the whales, seals, and polar bears of the ice floes.

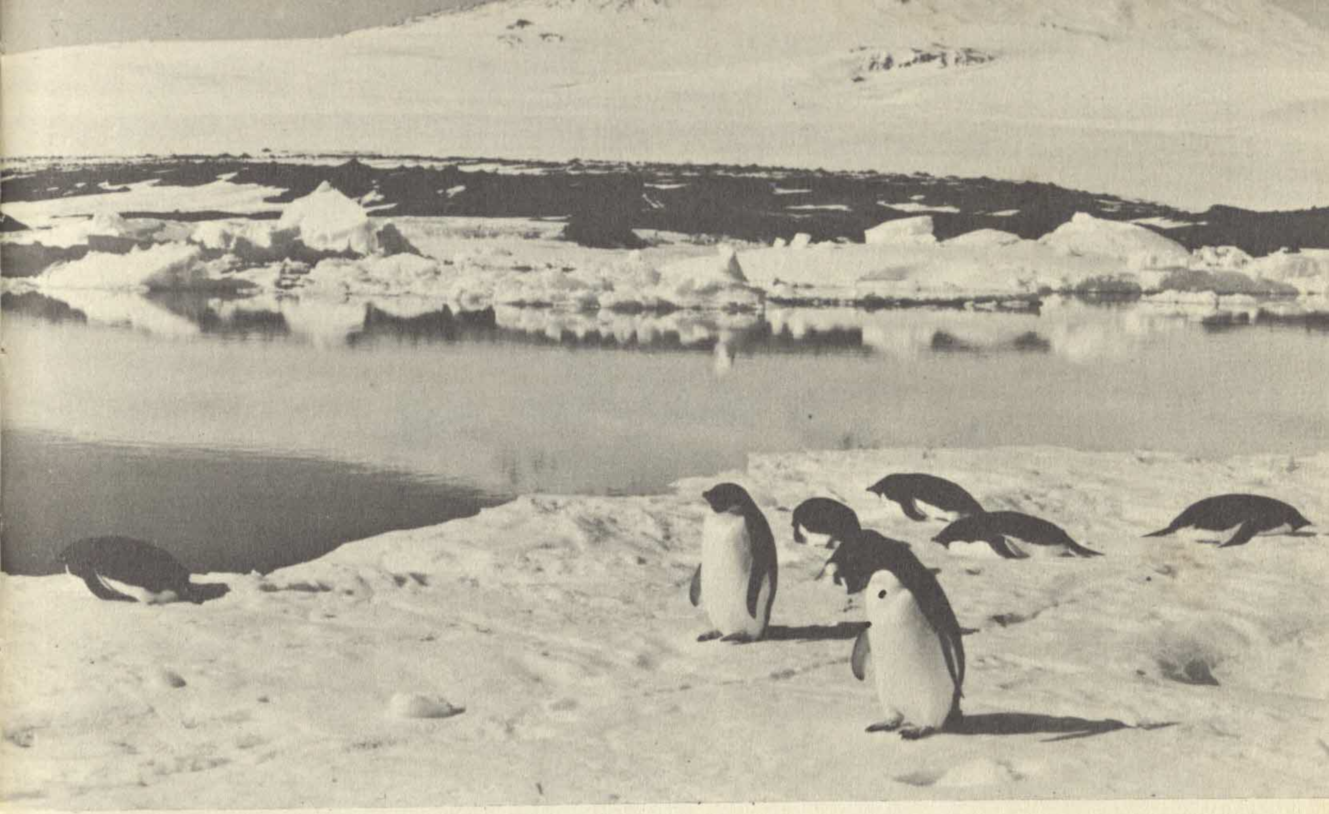
On the floor of the ocean, six miles beneath the surface, where the pressure of water is nine tons to the square inch, strange fish are able to live. They eat the dead creatures which sink down from higher levels, for at these depths there is no light and therefore no plant life.

Although every part of the sea supports some form of life there are areas of Earth's land surface where nothing will live at all. The only animal dwellers of the Antarctic continent are the penguins and a few insects which are found around its coasts; and lichens are its only plants. Nothing can live in the poisonous brine of the Dead Sea or more than a few miles above the surface of the Earth, though some insects and BACTERIA are swept up into the STRATOSPHERE where they survive for a short while.

Even on the plains of Arctic TUNDRA, ice bound and apparently barren for nine months of the year, there are many plants and animals which enjoy a few months of vigorous life. The summers are so short and the rays of the sun so lacking in strength that only the top few inches of the ground thaws and allows small rooted plants to grow. But during this brief summer when it is light for 24 hours each day, bright forget-me-nots and poppies are among the flowers which form a many coloured carpet; the hum of insects fills the air and ptarmigan and caribou join the great musk oxen—animals which look as if they need more satisfying food than the simple herbs upon which they browse and seek out beneath the winter snow.

The animals of the TUNDRA have to be patient and cunning in their search for food for the Arctic winter is a hungry time. Yet, protected by fur and layers of fat, helped by instinct which tells them where to hunt and where to hide, and how to store their food, they survive in a land which would spell death to an animal from a temperate region.

We know that nothing can live without water and so we think of deserts as dry, sand covered regions where neither plants can grow nor animals make a home. Not all deserts are seas of drifting sand, however, and in some regions, such as the North American Desert of California, a little rain does fall though it comes in sudden, heavy and brief



The penguin lives on the Antarctic coasts. Its wings are useless for flying but it has no enemies from which it needs to fly. With its smooth body and warm coat of down it is at home in the water and can endure the severe cold of Antarctica. The creatures of the desert have different problems to solve. (Photos: Paul Popper Ltd.)

thunderstorms. Although, in such places, human beings would die of thirst or heat stroke many animals are able to enjoy a healthy life. Through their widespread roots cactus plants are able to soak up from one shower, a large amount of water which they store in their thick juicy stems. Unlike plants in wet regions the plants of the desert must not allow much moisture to escape through their leaves. Some have tiny leaves, some lose their leaves altogether during the long dry months and others lie as shrivelled dry seeds on the desert floor to burst forth into gorgeous flowering plants which grow to produce more seeds in the weeks after the rain has fallen.

Though animals need water as much as plants do, some desert creatures pass their whole lives without drinking a single drop. They get all they need from the thick, juicy cactus stems or from the bodies of other animals which they eat. The kangaroo rat can even make moisture within its own body. By chemical processes it changes the substance of dry seeds into water sufficient for its own needs. So efficient are its kidneys that it could even manage to satisfy itself by drinking sea water if it was offered any.

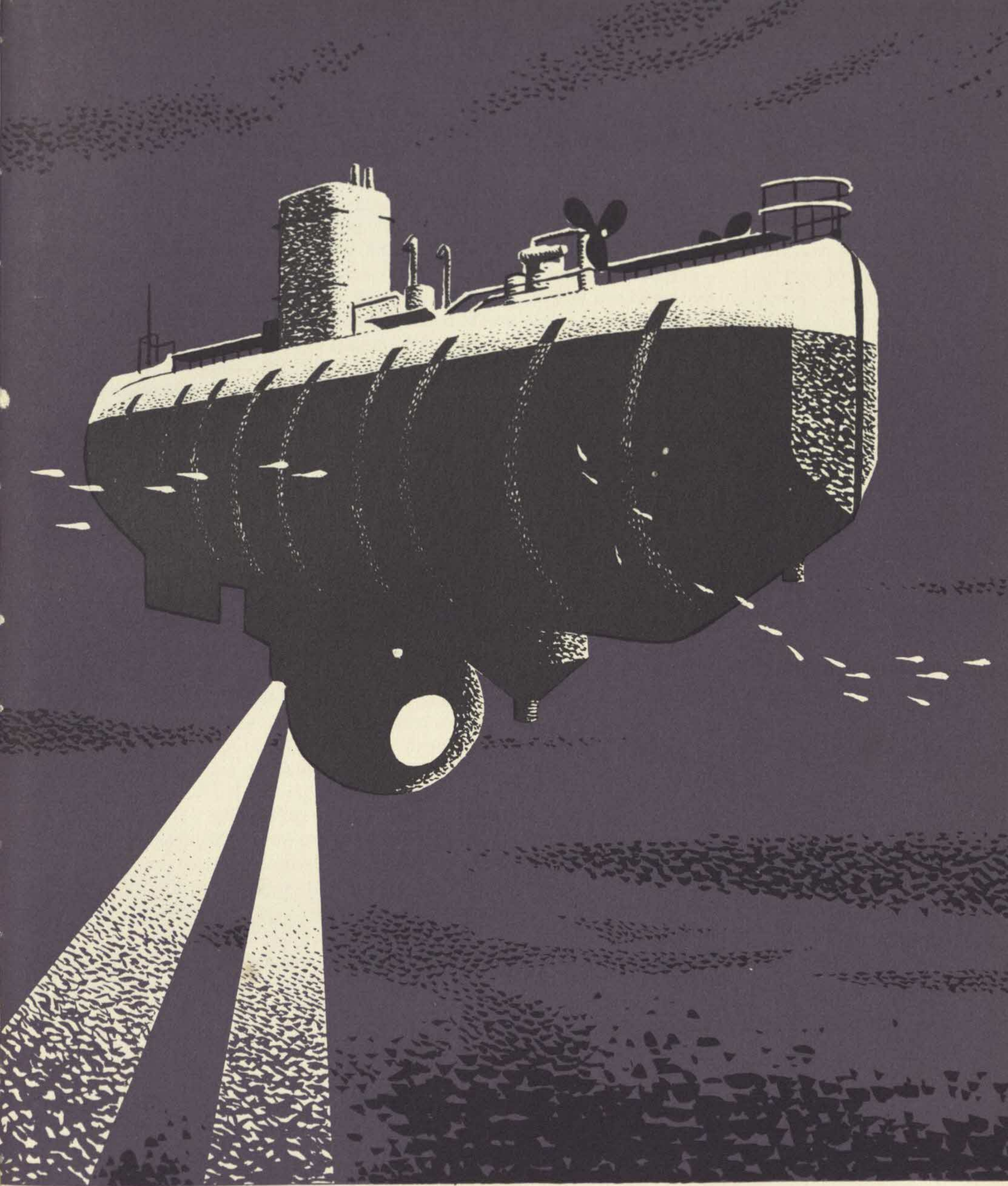
From the depths of the Pacific to the slopes of Everest, from the Arctic barrens to the Amazon jungle and from the Polar seas to the Californian desert, animal life can be found. The temperature, the amount of water, the rocks and soil, the height and the depth all join to decide what type of plants shall grow and what type of animal shall feed on them. It is because there are so many different forms of animal life that there are few parts of the world which are completely uninhabited. But because the bodies of animals are designed to do special jobs in a particular place, most animals are unhappy and many will die if they are forced to find a living in different surroundings.

Man's body is not made for such special conditions and although he can neither endure extreme cold nor great heat and dryness he can live both in the Arctic and on the Equator; whereas each type of animal prefers to stay in the region to which it is best suited. There are differences between the Greenland Eskimo and the Dinka tribesman of the Sudan but they are both men and, provided they exchanged clothes and habits, they could live and work in each other's homes although neither might feel particularly happy! Because Man's body is not specialized he can adapt himself to many different climates and eat many different types of food.

As well as a more adaptable body, Man has a better brain and more skilful hands than any other animal, and with these advantages he has been able to live and work in places where no animal could survive. With warm clothes, insulated buildings and reliable heaters explorers have worked at the South Pole and scientists in northern Greenland and on the Arctic ice cap. At Kalgoorlie in the Western Australian desert there is gold but nothing to drink, yet the desire for gold is so great that pipes have been laid 200 miles across the desert to bring water to the town.

With the help of the Bathyscaphe Man can study the remotest depths of the sea; the atomic submarine can navigate under the polar ice; and oxygen breathing apparatus can assist mountaineers to scale the highest mountains. Yet Man cannot settle or work in any of these places for, in order to live in them, he needs to carry with him a miniature of his own world.

The shape of the world affects Man's way of life. He has been a wandering herdsman on the desert fringes, a hunter in the Arctic and a farmer in the forest clearings. His industries have grown up where coal or iron are found and he has built his cities where ships can lie at anchor or where farmers and merchants have found it convenient



In the metal sphere of the Bathyscaphe two men descended more than six miles into the ocean. Above them was a large tank filled with petrol which helped them to float to the surface again.

to meet and do business. It may also be true that his way of thinking and acting have also been affected by where he lives. The changeable weather of Western Europe is more stimulating than the heat of the tropics, and Europeans have had to invent and make the comforts, machines and buildings which are neither wanted nor needed by the South Sea Islander.

But Man is not at the mercy of his surroundings. He can drain marshes to make farmland, dam rivers to make reservoirs and artificial waterfalls which provide electric power; he can lead water into the desert and take NITRATES from the desert's face to spread on his fields at home. He can, by careful ploughing and wise choice of crop, make food grow where none grew before; or he can, through neglect or ignorance, turn a fertile land into a SOIL ERODED wilderness. He can take plants and animals from one land to another and make a fortune as he did when rubber plants were shipped from Brazil to Malaya or when sheep were brought to graze on the Canterbury plains of New Zealand. He can also, however, upset the balance of Nature and make for himself trouble for years to come as when he took the prickly pear cactus to Australia in the hope that it would provide food for his cattle; and turned loose several dozen bunny rabbits to remind him of his home in England! The cactus spread like a forest fire and the rabbits became an expensive and obstinate pest.

One of the reasons for studying Geography—the rocks, the soil, the weather and the ways of the sea—is that we may plan how to make the best use of the world and all that it provides; to know what will help and what will hinder us in our search for food and comfort; to discover when to interfere and when to leave alone; and to learn why the Earth and air sometimes become violent so that precautions may be taken when danger threatens.

Of course there is another reason for studying the heavens, the Earth and the waters around the Earth—*curiosity*! We want to know about stars and space, about the ocean depths and the way Earth is made because these things are interesting. So we will go on exploring, measuring and searching with telescopes and microscopes even though the things we learn may seem to be of no use at all.

Man is learning more about the atmosphere from the weather balloon. Its instruments transmit facts about the state of the air and its diamond-shaped reflector enables radar to follow it on its flight.

SOME FACTS AND FIGURES

THE UNIVERSE:

Distance of nearest GALAXY	1,500,000	light years
Distance of nearest star (apart from the Sun)=PROXIMA CENTAURI	4.3	light years
	or 25 BILLION	miles
Diameter of Milky Way GALAXY	= 100,000	light years
One Light Year	$=5.8 \times 10^{12}$	miles
	or nearly 6 BILLION	miles
Speed of light	= 186,000	miles per second
	or 670,600,000	miles per hour

THE SOLAR SYSTEM OR SUN'S FAMILY:

Sun to Mercury	36,000,000	miles
Sun to Venus	67,000,000	miles
Sun to Earth	93,000,000	miles
Sun to Mars	142,000,000	miles
Sun to Pluto	3,500,000,000	miles
Earth to Moon	239,000	miles
Diameter of Sun	864,000	miles
Diameter of Jupiter (largest planet)	90,000	miles
Diameter of Moon	2,160	miles
Temperature of Sun's surface	10,800	degrees F.

EARTH:

Diameter at Poles	7,900	miles
Diameter at Equator	$7{,}926\frac{2}{3}$	miles
Circumference at Equator	24,902	miles
Highest point above sea-level—Mount Everest	29,002	feet
Deepest place in the ocean—Marianas Trench, near Guam in the Pacific	35,958	feet
	or 6.8	miles

(In January 1960 Lieutenant Walsh, U.S.N. and Professor Jacques Piccard descended to 35,800 feet in a *Bathyscaphe.*)

Lowest known point of land surface of Earth is in Marie Byrd Land, Antarctica, where the rock beneath the ice is 5,050 feet below sea level.

Deepest Lake—Lake Baikal, Central Siberia	6,364	feet
Lowest visible place where man may walk—the shores of the Dead Sea ... below sea level	1,286	feet

THE WEATHER:

Highest recorded air temperature (in screen 4 ft. above ground) —on 13th September, 1922 at Azizia, near Tripoli, N. Africa = 136.4 degrees F.

Hottest place on Earth—Lugh Ferrandi in the Italian Somaliland —annual *average* temperature ... ... = 88 degrees F.

Temperature on ground in the rays of the Sun—in Sudan, Africa = 211 degrees F.

Lowest recorded temperature—1958—425 miles from the South POLE OF INACCESSIBILITY at height of 12,000 feet ... ... = – 114 degrees F.

and U.S. Station, South Pole—17th September 1957 ... = – 102 degrees F.

Coldest place permanently inhabited—Verkhoyansk in N.E. Siberia, Russia—February 1933... ... ... = –90 degrees F.

(This town in the TUNDRA has a great range of temperature for in July 93 degrees F. has been reached and its July *average* is 60 degrees F.—the same as S.W. Ireland.)

Wettest recorded place on Earth—Cherrapunji, Assam, N.E. India:

Average yearly rainfall ... ... = 450 inches

During year 1861 Cherrapunji received ... ... 905 inches

During July alone of 1861 Cherrapunji received ... ... 366 inches

Heaviest rainfall recorded in one day—14th July, 1911—at Baguio, Luzon, Philippines—during a typhoon ... ... = 46 inches

For comparison:

On an *average* London receives 24½ inches per year.

Largest recorded hailstones fell at Potter, Nebraska, U.S.A. on 6th July, 1928. Some weighed 1½ lb. and measured 17 inches in circumference.

DEEPEST MINE:

Champion Reef, Mysore, India ... ... 10,144 feet below the surface

DEEPEST MAN-MADE HOLE:

At Pecos County, Texas, U.S.A. in June 1958, a boring searching for oil passed 22,570 feet (4.27 miles).

* * * *

Throughout this book the temperatures are given in degrees Fahrenheit, but we often use the Centigrade Scale too. To change degrees F. into degrees C., subtract 32, divide by 9 and multiply by 5, e.g.—

$$\begin{array}{l} 59 \\ -32 \\ \hline \dfrac{27 \times 5}{9} = 15 \text{ degrees C.} \end{array}$$

GLOSSARY AND INDEX

A list of words which are to be found in the book together with their meanings.

ALLUVIUM. Sand, silt and gravel laid down by a river ... 41

ANTIPODES. The place on Earth's surface directly opposite to where we are standing. The antipodes of Britain are to the south of New Zealand where there is a group of islands known as Antipodes Islands. The antipodes of New York are in the Southern Ocean south-west of Australia ... 24

ASTEROIDS. Small PLANET-like bodies most of which travel in a path between the ORBITS of Mars and Jupiter. Some take other paths and occasionally collide with planets ... 12

ASTRONOMERS study stars and other heavenly bodies in order to learn their size, distance and movements ... 5

ATLANTIS. There is a legend that once there was a land between Africa and America. Old stories tell of the destruction of this land by earthquake and TIDAL WAVE 21

ATMOSPHERE. The layer of gases which form the air around a PLANET 10/39/44/48/54

BACTERIA are sometimes known as 'germs' or 'microbes'. There are many different types; some are beneficial and some are Man's enemies. They may be as small as .0001 millimetre and they live in water, soil, food, sewage and our own bodies ... 49/52/54

BILLION. In Britain, and in this book, a billion is a million million $= 10^{12} =$ *one* followed by twelve *noughts*. In France and America a billion is a thousand million $= 10^9 =$ *one* followed by nine *noughts* ... 6/8/59

BLOCK MOUNTAIN. A mountain formed when part of Earth's crust is pushed up between FAULTS ... 36

CENTRIFUGAL FORCE. The force which affects a whirling object which will fly away unless it is held in check. If you whirl a bucket of water around your head centrifugal force will cause the water to press against the bottom of the bucket and none will spill ... 15

CONCAVE. Curving inwards, the opposite of *convex* ... 42

CONSTELLATION. A pattern of stars in the sky which appear to be near each other and remind ASTRONOMERS of a familiar shape ... 6

CONTINENTS. The chief unbroken land areas of the world. They are Europe and Asia, North and South America, Africa, Australia, Antarctica ... 19

CORAL POLYPS. Small tube-like animals which live in shallow tropical seas. Their skeletons have built the coral reefs and islands ... 32/33

DELTA. The fourth letter of the Greek alphabet is Δ—pronounced *delta*—and this is the shape formed by banks of ALLUVIUM when a river drops material at its mouth 40

DIATOMS. A type of microscopic floating sea plants ... 54

ELLIPTICAL. Having an oval shape ... 14

ERODED. Worn or eaten away ... 45

EROSION. The wearing away of the land by water, wind and ice ... 43/47/54

ESCARPMENT. A very steep slope on one side of a hill ... 36

FATHOM. A measurement of length equal to 6 feet ... 21

FAULT. A crack in the Earth's crust 36/38

FOSSILS. Traces of plants or animals found in the rocks of the Earth's crust ... 29/35

GALAXY. A vast system of millions of stars 5/6/8/59

GEOLOGIST. One who studies rocks either to find out more about the past or to learn more about what is underneath us 29/30/31

GEOPHYSICIST. A scientist who is interested in the structure of the Earth and the laws which govern its movements 27/29

GEOSYNCLINE. A large trough or basin in the rock STRATA 34/35

GLACIER. A slow moving river of ice which flows from the snow covered high ground to the warmer valleys 41/51

GORGE. A deep, narrow valley with steep sides 41

GRAND BANKS. A shallow area of the sea near Newfoundland, famous for its fisheries 43

GRAND CANYON. A canyon is a large GORGE. The Grand Canyon of the Colorado River, U.S.A. is the largest in the world 41

GRAVITY. A sort of magnetic force by which everything in the UNIVERSE has an attraction for everything else. It is gravity which holds Earth to Sun, and Moon to Earth 24/28

GREENWICH MEAN TIME (G.M.T. for short) is the time observed all over Britain and is the sun time at Greenwich Observatory on LONGITUDE '0'. New York time is 5 hours behind Greenwich and Melbourne is 10 hours in front 19

GROYNES. Low walls built out to sea to prevent sand and shingle from travelling along a beach 45

HEMISPHERE. Half of a SPHERE. The Equator divides the world into the Northern and the Southern Hemispheres 16/22

HUMUS. A vital part of the soil consisting of rotted animal and vegetable matter 40/50

ICE AGE. A period which ended some 12,000 years ago when ice covered large areas of Europe, Asia and N. America 42

IGNEOUS. Rocks which were formed by the great heat of Earth's interior. The Latin word *ignis* means 'fire' 31/32/33/38/39

INTERNATIONAL DATE LINE. An imaginary line which runs from north to south through the Pacific on or near to LONGITUDE 180 18

INTERNATIONAL GEOPHYSICAL YEAR (I.G.Y.). A period of 18 months during 1957 and 1958 when scientists of many nations made experiments in the hope of discovering fresh facts about the Earth, its oceans, and its ATMOSPHERE. It was during the I.G.Y. that the first crossing of the Antarctic CONTINENT was made ... 23

IONOSPHERE. A layer of the ATMOSPHERE above the STRATOSPHERE and beginning about 55 miles above the Earth. Its thin air consists of electrically charged particles or 'ions' which reflect radio waves 53

JET STREAMS. Currents of air which whirl around the Earth at a height of 7 or 8 miles and at speeds of up to 300 miles per hour 53

KON TIKI. The name of the balsa wood raft on which the Norwegian Thor Heyerdahl and his companions crossed the Pacific with the aid of a west flowing current ... 24

LONGITUDE. Lines of longitude are drawn from north to south on our maps to show how many degrees east or west of Greenwich a certain place is. All lines of longitude meet at the poles and form angles with each other. Any place in the world may be pinpointed by giving its *longitude* and Latitude 17

MEANDER. A river which loops from side to side *meanders*. The word comes from the River Meander, a twisting river in Asia Minor 41

MERIDIAN. A line of LONGITUDE. The *prime* meridian from which all others are measured passes through Greenwich, England 18/19

METAMORPHIC. Rocks which have been changed into new forms 31/33

METEOROLOGIST. A scientist who studies the weather and its causes ... 22

NEBULA (plural NEBULAE). A cloud of stars and gas 6/7/8

NITRATES. Chemical salts containing nitrogen 48/58

OCEANOGRAPHER. A scientist who studies the oceans 21

ORBIT. The path taken by one heavenly body moving around another one ... 12/13

P. and S. WAVES. Primary and Secondary earthquake waves which always arrive in the same order. P. and S. can also stand for *push* and *shake waves* 27

PLANETS are heavenly bodies which revolve around a sun. Earth is a planet... 5/7

PLANKTON. Microscopic plants (e.g. DIATOMS) and animals which float in seas, lakes and rivers and form the food of many fishes and of whales 54

POLDERS. Areas of Holland which have been reclaimed from the sea 45

POLE OF INACCESSIBILITY could be called the remotest place on Earth for it is the point in Antarctica farthest from the sea. It is 14,000 feet above sea-level—4,000 feet higher than the South Pole. During the I.G.Y. a Russian team established there a base named Sovietskaya 60

PROTEINS. Chemical compounds which form a large part of all living matter. It is essential that our food contain some protein 48

PROXIMA CENTAURI. The star 'Proxima' (Latin for *nearest*) of the CONSTELLATION Centaurus. It is the nearest star to our Sun 6/8/59

RIFT VALLEY. A valley formed when the land surface sinks between two parallel FAULTS 36

SATELLITES. Small attendants to the PLANETS as the Moon is to the Earth 12

SEDIMENT. Dregs which sink to the bottom of such liquids as wine or pond water 20

SEDIMENTARY rocks are those which have been laid down by water, wind or ice 31/32/33/34

SEISMOGRAPH. An instrument which records earthquake waves by making wavy lines on a revolving drum 27

SIAL. The granite type rocks which form the CONTINENTS. They are so called because they consist chiefly of SIlicon and ALuminium 27/28/29/35/38

SIMA. The basalt type rocks which lie beneath the continents and may form the ocean bed. They are so called because they consist chiefly of SIlicon and MAgnesium 27/28/29/35/43

SOIL EROSION. Destruction and wearing away of soil by wind or rain—a very serious problem which farmers are solving by such devices as planting trees or special ways of ploughing 40/58

SOLAR SYSTEM. Our Sun and the family of PLANETS which revolve around it 12/14/15

SOLID GEOLOGY. The study of the rocks beneath the SEDIMENTARY layer often found at the surface... 31

SPECTROSCOPE. An instrument for breaking up light into its SPECTRUM and examining it 8/13

SPECTRUM (plural SPECTRA). The coloured band formed when a ray of light passes through a prism 8

SPHERE. A perfectly round ball shape 15

SPRING TIDES. Exceptionally high tides which occur round about the time of full moon and new moon 24/44/45

STRATA is the plural of *stratum* meaning a layer (usually of rock). A sandwich has *strata*: bread, butter, cheese, butter, bread 34/36

STRATOSPHERE. The second layer of the ATMOSPHERE where the temperature no longer falls as one goes higher 53/54

SURFACE GEOLOGY. The study of the topmost rocks of Earth's surface... 30

THEORY OF CONTINENTAL DRIFT. An idea that the CONTINENTS floated away from their original places on a 'sea' of dense rocks. (See *Journey to the Centre of the Earth*) 29/35

TIDAL WAVES are wrongly named for they are not caused by the rise of the tide but by earthquakes on the ocean bed. The Japanese have great experience of such waves and their word *tsunami* is used to describe them. The approach of *tsunami* is heralded by the sea drawing back a great distance and leaving its bed uncovered ... 38

TRADES. Winds which blow regularly towards the Equator from the north-east and south-east. In the days of sailing vessels these reliable winds helped trading ships upon their way 22

TROPICS. The region lying about the Equator between the TROPIC OF CANCER and the TROPIC OF CAPRICORN. As the Sun's rays never slope very much within the tropics the weather is generally hot 15/16

TROPIC OF CANCER. The parallel of Latitude 23½ degrees north of the Equator. 16

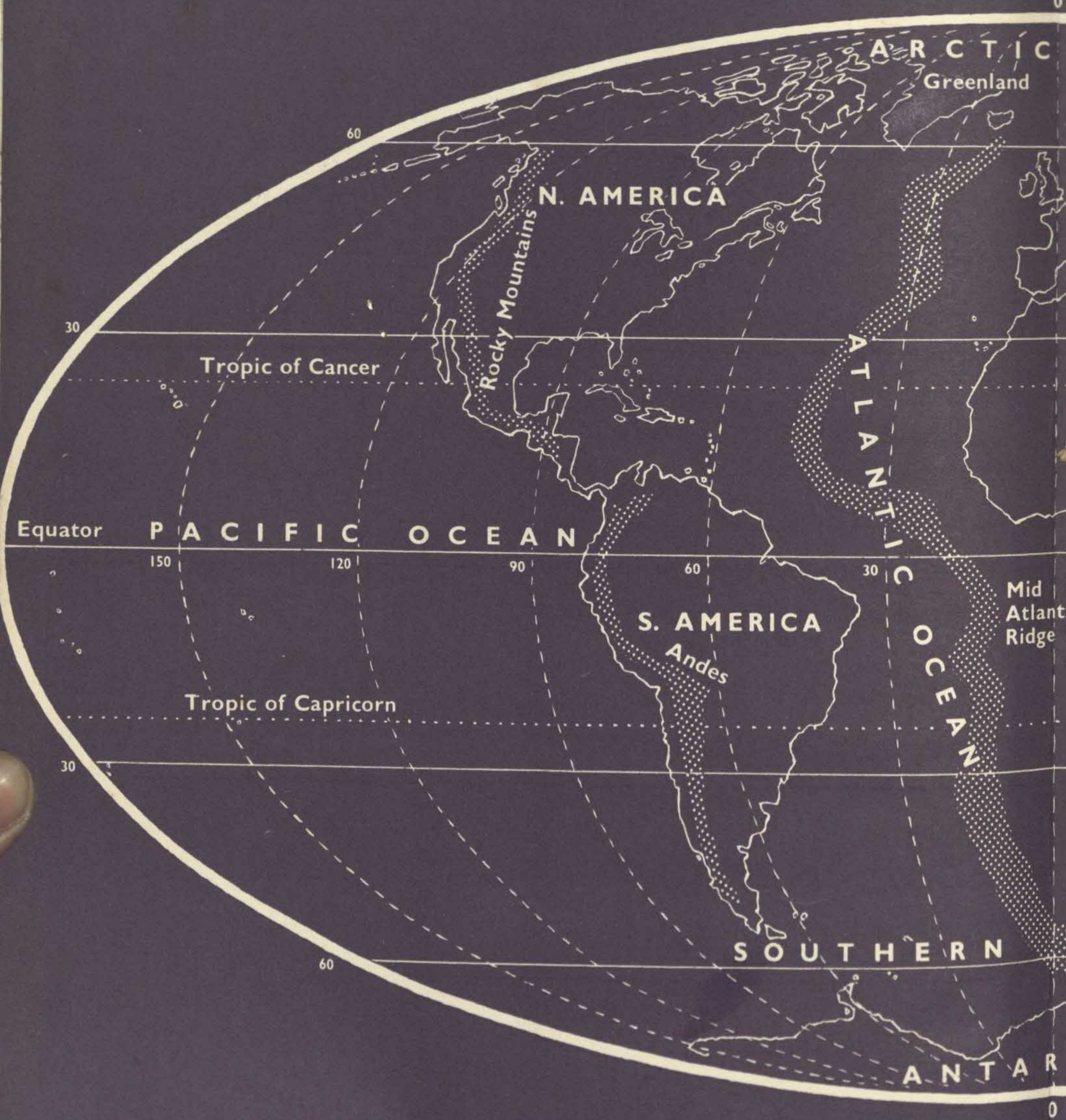
TROPIC OF CAPRICORN. The parallel of Latitude 23½ degrees south of the Equator 16

TROPOSPHERE. The lowest layer of the ATMOSPHERE within which the temperature falls as one goes higher 53

TUNDRA. The treeless plains bordering the Arctic Ocean 54/60

UNIVERSE. The whole system of GALAXIES, stars, PLANETS and everything which they contain 6

YOUNG FOLD mountains were formed by folding fairly recently in Earth's history. 35


0
ARCTIC
Greenland
60
N. AMERICA
Rocky Mountains
30
Tropic of Cancer
ATLANTIC OCEAN
Equator
PACIFIC OCEAN
150
120
90
60
30
Mid
Atlant
Ridge
S. AMERICA
Andes
Tropic of Capricorn
30
60
SOUTHERN
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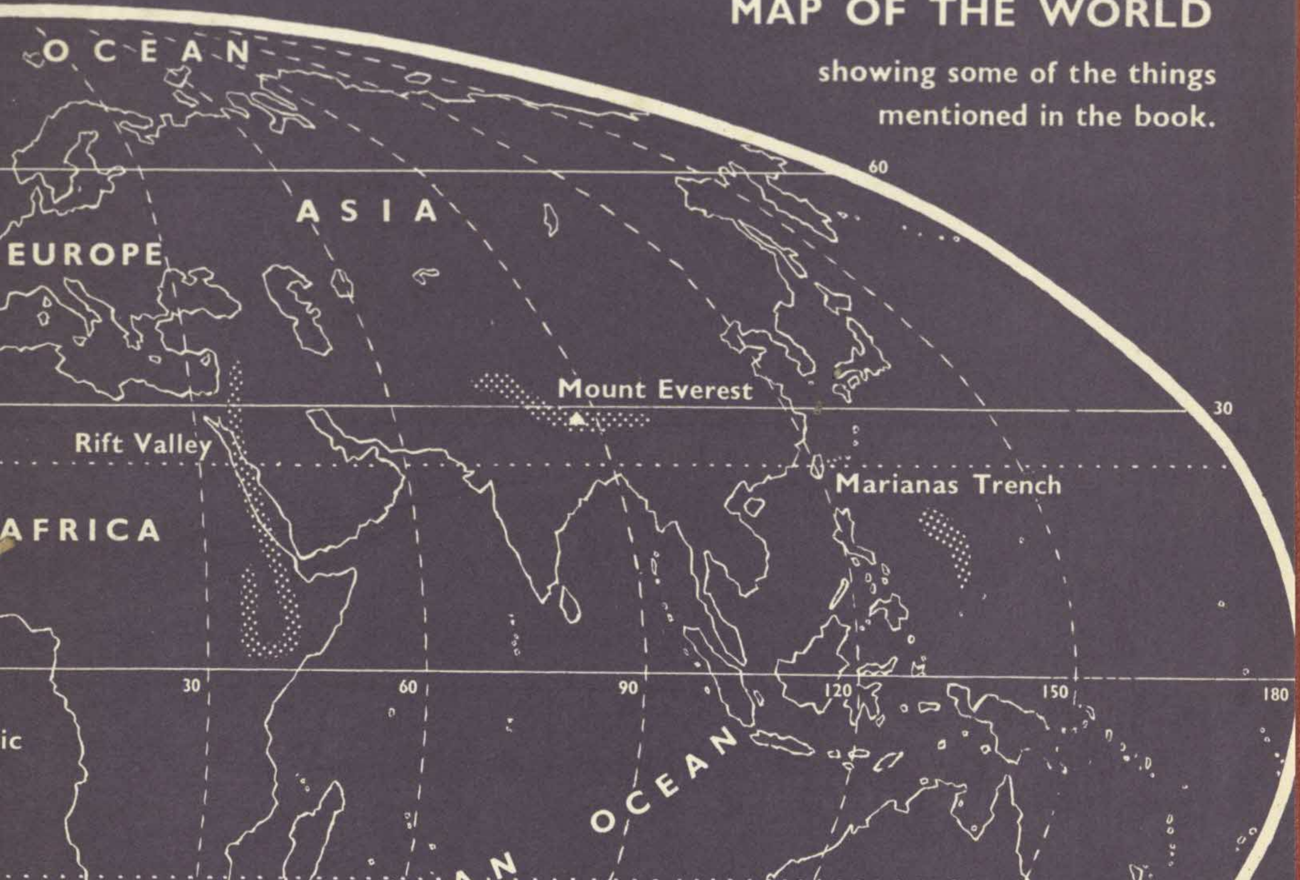
MAP OF THE WORLD

showing some of the things
mentioned in the book.



This map is drawn on Mollweide's Projection. It is a good way of showing the round world on a flat paper.

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